

AN OVERVIEW OF THE COVERAGE WITH ENC IN THE MESOAMERICAN REGIONAL HYDROGRAPHIC COMMISSION AND THE CARIBBEAN SEA - MACHC

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Abstract

Hydrographic offices worldwide started the production of Electronic Nautical Charts (ENCs) based on paper nautical charts, generating various designs in their schemes.

The design of electronic nautical cartography schemes in the Regional Hydrographic Commissions (RHC) is analyzed, in order to understand the existence of schemes adopted by an entire region, or electronic nautical cartography schemes defined by countries with the capacity to produce them worldwide. The review allows us to know the state of the art in the regional schemes, methodologies and / or parameters used in their definition, and level of compliance with international regulations.

In addition, questionnaires were carried out, which were used to acquire complementary information on hydrographic services, and this combined with the analyzes will determine the strengths and weaknesses in the current ENC coverage. Taking maritime safety into account, the investigations were conducive to presenting a methodological proposal for regional standardized ENC schemes.

This article has been organized into five points, the first one presents the analysis of the coverage of current electronic charts, taking into account the metadata of the coverage used by the different Regional Hydrographic Commissions. In the second, a survey carried out to several Hydrographic Services is presented, including: the review and registration of relevant aspects of the ENC schemes at the RHCs level, as well as the socialization and issuance of the survey to the RENC Member States. IC-ENC; in the third, the results of the analysis of the information collected on the designs of the current ENC schemes in the RHCs that responded to the survey; the fourth presents the strengths and weaknesses found in specific cases of the current ENC schemes; and finally, in the fifth, the work in progress by the subgroup for the ENC Regional Scheme in the MACHC is evidenced.

Key words: Electronic Navigation Charts; ENCs; Schemes; MACHC; Hydrographic Service; Information System and Visualization of Electronic Charts.



Résumé

Les Services hydrographiques du monde entier ont commencé à produire des cartes électroniques de navigation (ENC) à partir des cartes marines papier, générant ainsi divers modèles de schémas.

La conception des schémas de cartes électroniques de navigation dans les Commissions hydrographiques régionales (CHR) est analysée, afin de connaître



Résumé (suite)

l'existence de schémas adoptés par une région entière, ou de schémas de cartes de navigation électroniques définis par des pays ayant la capacité de les produire dans le monde entier. Cette étude nous permet de connaître les dernières avancées des schémas régionaux, les méthodologies et/ou les paramètres utilisés dans leur définition, et leur niveau de conformité avec les réglementations internationales.

En outre, des questionnaires ont été réalisés et ont permis d'obtenir des informations complémentaires sur les services hydrographiques, ce qui, combiné aux analyses, permettra de déterminer les forces et les faiblesses de la couverture actuelle en ENC. En tenant compte de la sécurité maritime, les investigations ont permis de présenter une proposition méthodologique pour des schémas ENC régionaux normalisés.

Cet article s'articule autour de cinq points : le premier point présente l'analyse de la couverture des cartes électroniques actuelles, en tenant compte des métadonnées de couverture utilisées par les différentes Commissions hydrographiques régionales. Au second point, une enquête réalisée auprès de plusieurs Services hydrographiques est présentée, comprenant : l'examen et l'enregistrement des aspects pertinents des schémas ENC au niveau des CHR, ainsi que la socialisation et la diffusion de l'enquête auprès des Etats membres du RENC IC-ENC ; au troisième point, les résultats de l'analyse des informations recueillies sur la conception des schémas ENC actuels dans les CHR qui ont répondu à l'enquête ; le quatrième point présente les forces et les faiblesses constatées dans des cas spécifiques de schémas ENC actuels ; et enfin le cinquième point met en évidence le travail en cours du sous-groupe pour le schéma régional d'ENC au sein de la CHMAC.

Mots clés : Cartes électroniques de navigation ; ENC ; Schémas ; CHMAC ; Service hydrographique ; Système de visualisation des cartes électroniques et d'information.



Resumen

Los servicios hidrográficos de todo el mundo iniciaron la producción de Cartas Náuticas Electrónicas (ENCs) basadas en las cartas náuticas de papel, generando varios diseños de esquemas.

Se analiza los diseños de esquemas de cartografía náutica electrónica en las Comisiones Hidrográficas Regionales (CHR) para conocer la existencia de esquemas adoptados por una región entera, o esquemas de cartografía náutica electrónica definidos por países con la capacidad para producirlos de manera global. Este estudio permite conocer los últimos avances en los esquemas regionales, las metodologías y/o parámetros utilizados en su definición y su nivel de cumplimiento de la normativa internacional.

Además, se realizaron cuestionarios que se usaron para adquirir información complementaria sobre servicios hidrográficos, y esto combinado con los análisis determinará los puntos fuertes y débiles de la cobertura ENC actual. Teniendo en cuenta la seguridad marítima, las investigaciones fueron favorables a presentar una propuesta metodológica para esquemas ENC regionales normalizados.

El artículo está organizado en cinco puntos, el primero presenta el análisis de la cobertura de las cartas electrónicas actuales, teniendo en cuenta los metadatos de



Resumen (continuación)

la cobertura usada por las diferentes Comisiones Hidrográficas Regionales. En el segundo se presenta una encuesta realizada a varios Servicios Hidrográficos, incluyendo: revisión y registro de aspectos relevantes de los esquemas ENC al nivel de las CHRs, además de la socialización y remisión de la encuesta a los Estados Miembros del RENC IC-ENC; en el tercero, los resultados del análisis de la información recogida sobre los diseños de los esquemas ENC actuales en las CHRs que respondieron a la encuesta; el cuarto presenta los puntos fuertes y débiles encontrados en casos específicos de esquemas ENC actuales; y finalmente en el quinto se evidencia el trabajo en curso por el subgrupo para el Esquema Regional de ENC en la MACHC.

Key words: Electronic Nautical Charts; ENCs; Schemes; MACHC; Hydrographic Service; Information System and Visualization of Electronic Charts.

1. INTRODUCTION

The International Hydrographic Organization (IHO), with the purpose of unifying the use of digital cartography and the exchange of hydrographic data, published the S-57 Digital Hydrographic Data Transfer standard for the production of electronic nautical cartography (IHO, 2000), which allows paper nautical chart data to be transferred digitally in a standardized form from the elements of an Electronic Navigation Chart (ENC) (Zou, Wang, & Wang, 2012).

The ENC is defined as: A standardized database in terms of content, structure, and format, published by Hydrographic Services under the authority of a government, for use in an electronic chart information display system (ECDIS). ECDIS is adopted by the International Maritime Organization (IMO) as part of the requirement on board ships which must carry the official ENCs for safe navigation (IMO, 2006).

Therefore, the International Hydrographic Organization coordinates world hydrographic activity, with the support of the Regional Hydrographic Commissions (RHC), which are 16 geographical divisions, made up of IHO member states with common interest, urging countries to contribute and unite efforts in planning, execution of hydrographic surveys and production of cartography. However, despite the recommendations of the IHO, it is not guaranteed that countries will fully follow or abide by the regulations.

2. BACKGROUND

As of the fifth meeting of the Hydrographic Commission of the Caribbean Sea and MesoAmerica (MACHC) in 2002, several hydrographers from this region discussed the first guidelines for the creation of electronic navigation charts for the region, using as a basis the existing international paper nautical chart scheme (CHRIS, 2003). It is important to bear in mind that the cartography planes are defined by each State in a sovereign way, in which the charts and scales necessary to cover a territory were obtained. However, there are "International Paper Chart Schemes", which are established for the different Regions. These schemes define the areas covered, the chart scales and the countries responsible for their production. This work is carried out at the regional level but coordinated by the IHO working groups, based on specifications issued by the same Organization, contained in publications such as S-11, for medium and small scales in order to meet the needs of international maritime traffic safety.

In subsequent meetings, member countries that make up the MACHC, such as Brazil, Colombia, Cuba, France, Mexico, Netherlands, Suriname, United Kingdom, United States of America and Venezuela, have reported the progress of their cartographic production within the framework national and international, both paper and electronic. In order to achieve adequate coverage of the ENCs, since the twelfth meeting of the MACHC in 2011, the production of official electronic charts in the region has been encouraged and the availability of the data used in their construction has been promoted through the Committees; Electronic Chart (ECC) and International Chart (ICC), currently known as the MICC, (MACHC Integrated Chart Committee, 2011).

3. PROBLEMS IN ENC COVERAGE

The production of ENCs in the Caribbean has so far been carried out using the schemes that already existed for paper charts, which, although it was the easiest to implement, has generated several problems. The most important is that many cells (ENCs) have a significant overlap area, which although it was advisable for paper charts by facilitating the mariner to move from one chart to another during their route, generates several problems in the ENCs, when cells are presented with areas of irregular overlapping information, poor horizontal consistency and lack of information or gaps in the continuity of the cells, which prevents obtaining a uniform coverage (La Pira, 2010). The foregoing, mainly due to the fact that in the same ENC there are areas

overlapped by several nautical paper charts at different scales, which, when used in the creation of a single cell or electronic chart, generate the aforementioned inconsistencies.

Currently, electronic nautical cartography has been replacing paper charts, due to the work advantages offered by the use of ECDIS as a system, by integrating ship sensors and navigation aids, such as: log, gyrocompass, GPS, ENC's, RADAR, buoys, lighthouses, among others (Salgado Don, 2015; Śniegocki & Wieliki, 2010), which allows interrogation, visualization and filtering of the information according to the navigation route or maneuver that the navigator is developing, thereby improving their safety.

According to the Nautical Cartography Working Group of IHO, the use of paper charts has declined from 2008 to 2018 by around fifty percent worldwide, the production of electronic navigation charts has increased (NCWG, 2020). As evidence between 2014 and 2016, based on the production of 40 member countries of the International Center for ENC (IC-ENC) the growth was from 4,916 to 7,330 ENC's. One of the reasons for this increase in ENC production is the IMO regulations that make the use of ECDIS mandatory from 2012 and progressively until 2018 according to the tonnage of the vessels. In the IC-ENC report, for 2016 the increase in the production of electronic charts in the following countries stands out: Ecuador 71.4%, Venezuela 127.8%, Egypt 23.5%, Pakistan 16.7% and Chile 15%. (IC-ENC, 2017).

The reports of the working groups that make up the RHCs are essential for the monitoring of the cartographic production carried out by the working group on the world database of electronic navigation charts. (WENDWG). This group has recommended increasing the execution of the schemes for the nautical purpose or usage bands from 1 to 3, corresponding to the purposes of Oceanic, General and Coastal navigation managed in the scale ranges <1:1.499.999, 1:350.000 – 1:1.499 999 y 1:90.000 – 1:349.999 respectively, (IHO-IRCC9, 2017) This cartographic production should take into account the revisions of the IHO Strategic Plan, the IHO resolution to eliminate overlapping ENC's and the recommendations of the Regional Centers for Electronic Navigation Charts (RENC), on the importance of eliminating the overlap of the data.

Based on the status and progress in the worldwide electronic cartographic production described in the previous paragraphs; not having a regional ENC scheme adopted by the RHC has shown inconsistent coverage due to the various designs, difference between the handling of scales, data, and ENC coverage affecting maritime safety due to the irregularity in the presentation of the data. According to the analysis and results obtained through surveys, the strengths and weaknesses represented in the existing coverage were socialized before the annual meetings of the MACHC and the need to strengthen the RHC was apparent, therefore, through the Assembly it is created the Sub-Working Group for Regional Schemes of standardized ENC's, endorsed at the MACHC 20th meeting.

From the meeting 20th to June 2021 there are investigations involving the producing countries and leaders of the US, UK and CO subgroups who are investigating possibilities and options for the region's scheme, starting with the Oceanic usage band.

There are countries that are re - schematizing their charts to solve problems, as an example the USA (<https://nauticalcharts.noaa.gov/publications/docs/ENC-Transformation.pdf>), however it is done independently and not as part of a RHC scheme.

4. ENC PRODUCTION BY THE HYDROGRAPHIC SERVICES IN THE MACHC

In the case of the countries that make up the Caribbean Sea, there is a difference, because most do not have a hydrographic office and the nautical publications of these countries have been assumed by other nations, such as the United Kingdom, United States, Holland and France. This is especially true for the United States, who at the beginning of the 20th century made a great effort to carry out surveys and produce nautical charts in the Caribbean Sea and on the coast of America in the Pacific Ocean. Through the National Oceanic and Atmospheric Administration (NOAA) in the 90's, it began the production of its electronic charts from the digitization of

paper charts and is currently developing a strategy to transform nautical cartography. in the National Cartography Plan, in order to solve problems in its products, such as: duplication of information, elimination of cells with irregular shape compiled in 130 scales, among others (Office of Coast Survey, 2017).

1. ANALYSIS OF CURRENT ELECTRONIC CHART SCHEMES

To analyze the design of the regional cartographic schemes, information was pulled from the web portals of the Regional Hydrographic Commissions, the Value-Added Resellers (VARs) and the IHO catalog (**Figure 1**), whose information is provided by RENCs, Member States and distribution agencies.



Figure 1 : ENC coverage available by RHCs filtered for General navigation purpose, revised December 2019 Source: IHO online catalog

<http://iho.maps.arcgis.com/apps/webappviewer/index.html?id=06d967702c7f4094bbc5b4f8e485b712>

For the analysis of the current ENC schemes, a series of activities were carried out, which are listed below. The first two activities involved analysis of the Regional Hydrographic Commissions, based on the information available on the IHO portal:

- (i) The ENCs produced by the countries that make up each RHC were reviewed, examining the following aspects:

- The design of the ENC scheme: to identify, first, if there is a scheme approved and adopted by the countries of the region, which allows greater uniformity in the representation and consistency of the data; and second if the ENC design is completely adjacent or, on the contrary, information is lacking in the same navigation purpose (overlap and / or gaps).

- Metadata: allows for identification of the scales used in production and determination if they follow those recommended by the IHO standards, the cartographic production capacity of the

- (ii) Information was recorded on the aspects examined by each country of the RHC, taking into account metadata such as the producer country, navigation purpose, scale for each polygon that represents the ENC data coverage, as detailed in the **Table 1**.

Table 1 Record of aspects examined in the countries that make up the Regional Hydrographic Commissions, taking into account metadata of the ENC coverage

CHR ¹	There is a scheme adopted by the region	Adopts the scales recommended by the IHO	Producing agency code ² on the CHR	Scheme designs ³
USCHC	No	No	CA, GB, US	E_PC
MACHC	No	Partially	DO, US, GB, CU, BR, MX, VE, NL, PA, CO, SR, FR	E_PC / E_ENC
SWATH	No	Yes	AR, BR, UY	E_PC
SEPRHC	No	Partially	CL, CO, EC, PE	E_ENC / E_PC
NSHC	No	Partially	GB, IS, NL, DK, NO, BE, FR, DE, NL, IS	Grid / E_PC / E_ENC
NHC	No	Yes	DK, IS, NO	Grid / E_ENC
EATHC	No	Partially	ES, FR, GB, PT	E_PC
MBSHC	No	Partially	RU, FR, GB, IT, ES	E_PC / Grid, combined system
SWPHC	No	Partially	AU, NZ, GB, FR	Grid/ E_PC / E_ENC, combined system
EAHC	No	Partially	ID, GB, MY, PH, JP, KR, China (CN, C1)	Grid / E_PC
NIOHC	No	Partially	BD, GB, PK, IN, ID, EG	E_PC
SAIHC	No	Partially	GB, FR, IN, ZA, NO	Grid/ E_PC / E_ENC

In the **Table 1** the distribution of the designs in each one of the RHCs is appreciated, where the majority use the three designs, finding cases in the countries that use combined designs; For the MACHC Commission, it is the Equivalent to paper charts and Exclusive for ENC, in the purpose of coastal navigation.

The following activities were carried out exclusively for the ENCs that map the Caribbean Sea, considering the complexity in the production.

- (iii) The cartographic coverage for each related port or area of interest was reviewed, identifying the products for navigation purposes and scales established by producers.
- (iv) The horizontal consistency of the data was examined, filtering the ENCs by navigation purpose from the portal of the MICC committee of the MACHC, which contains the vector product, allowing the analysis of all objects according to the type of geometry, for:

Polygon: Depth Areas, Special Areas, Magnetic Variation, among others.

Line: Series of contours defined for the chart according to the scale or purpose according to the specifications, unify series for purposes taking into account the configuration of the safety contour between the ECDIS parameters; cabling, coastline, among others.

Point: Sounding, hazards, navigational aids, among other point objects that display value is applied to them in the ECDIS through the minimum scale attribute (SCAMIN).

- (v) The international paper chart scheme for the region was compared with the coverage of the ENC's published on the MICC committee portal, identifying whether the INT scheme was adopted by the countries for the production of electronic cartography.
- (vi) The results of the analysis were shared with the RHCs, RENCs and working groups of the IHO related to the subject, in order to receive suggestions and comments to substantiate the proposal to standardize regional schemes through a re-schematization to unify navigation purposes.
- (vii) A questionnaire was formulated and applied to the member countries of the RHCs and the RENCs, to provide feedback and complement the information analyzed, in order to know if the RHC has established standardized schemes in the region that the countries have approved and adopted, or on the contrary if the countries agree to re-schematize for navigation purposes that cover international waters, allowing to have a uniform coverage.

2. SURVEYS TO HYDROGRAPHIC SERVICES

This section develops the analysis of the results of the questionnaire to the member states of the Regional Center for electronic navigation charts.

In general, the analysis indicates that, close to three decades after having published the standard for electronic charts, the producing countries worldwide continue to work in the search for strategies and mechanisms for the continuous improvement of ENC's, in terms of quality, precision and updating.

During the socialization, in technical meetings of the electronic cartography working groups and IHO commissions, criticism and positive comments were received, which show the applicability and the benefit of being able to carry out the objective of Regional Schemes. The president of the International Center for ENC's (IC-ENC), asked if there are similar efforts in his region to that of the present work, giving the result that countries are working independently, due to challenges of sharing data between nations.

Consequently, the idea of presenting an academic questionnaire for IC-ENC members was raised, a commitment that was endorsed by them and supported by IC-ENC in accordance with action 5 of technical report TC03 / 19 (IC-ENC, 2018), in order to obtain more information about the commissions.

The most important aspects of the questionnaire are highlighted below.:

- (i) During the third IC-ENC technical conference of 2018, an action was agreed between the participating members, to answer a questionnaire for academic purposes for research.
- (ii) IC-ENC sent the survey to 44 member states, of which only 9 responded, in a period of five months. That is, 20.25%, which represents a difficulty in making decisions based on this instrument.
- (iii) Five countries do not have regular plans to maintain horizontal consistency between ENC's with border countries.
- (iv) The countries agree that the RHCs establish standardized regional schemes for Oceanic, General and Coastal purposes, however, the USA indicates that it would be a difficult task for the hydrographic offices. The difficulty lies in the origin of the data they used to create the ENC's, which leads to handling different levels of compilation scale in current ENC's, fearing that changing the compilation scales could create an ENC with poor data quality.

- (v) Regarding re-schematization, a negative response was received by one of the countries stating its commission works in a coordinated manner and, it does not consider it necessary to carry out a complete restructuring in terms of overlaps and gaps. The few remaining cases must be resolved (locally adjusted or modified) among the NCD producers involved; this is encouraged by the NSICWWG.
- (vi) Unify the compilation scale by navigation purpose, bearing in mind that the standards do not define scales for each usage band, on the contrary, a wide range of scales is recommended. Set a fixed minimum and maximum, and fixed defined values to use between this minimum and maximum for each band. With respect to this point, the Eastern Atlantic and Mediterranean regions already have these purposes standardized. No argument was received against this procedure.
- (vii) Three of the nine countries consider the prior review of ENC's by the RHC to be beneficial, they are countries that are strengthening capacities for the production of their ENC's, one of the countries is replacing the ENC's generated by the UKHO.

3. EVALUATION OF THE DIFFERENT DESIGNS OF CURRENT ENC'S SCHEMES

With the result of the questionnaire to the Member States, the information obtained during the analysis of the scheme designs in the RHCs is corroborated. (**Table 1**), of not having standardized regional schemes. In the **Table 2**, advantages and disadvantages of the diversity of designs of the current schemes are defined. The three evaluated designs are:

Design equivalent to a paper chart. It refers to when the ENC scheme preserves as a pattern the coordinates and scales of a scheme for paper nautical charts, and even the areas of overlap. On paper charts at the same scale, it is necessary that these areas exist to maintain continuity of data during change of charts.

Grid. It is a design using a network of lattices that show parallels of latitude and meridians of longitude, in a uniformly spaced manner.

ENC Exclusive Schematic Design. It corresponds to the electronic chart scheme based on the recommendations of the WEND principles, specifically in not duplicating data and avoiding gaps between cells for the same purpose, optimizing the information compiled from the different cartographic sources and generating a cell that provides the information according to the purpose. navigation.

4. WEAKNESSES AND STRENGTHS

The results corresponding to activities such as a review of designs, metadata, port coverage and consistency of electronic navigation charting schemes, classified into strengths and weaknesses as follows:

WEAKNESSES

- (i) Difference in the information published between the portals of the RHCs, IHO and the VARs commercialization catalog.

For the MACHC region, a specific case is presented, where there are differences between the cells reported in the portals of the MICC committee and the MACHC committee with respect to the ENC's that are available in the UKHO VAR catalog.

Table 2 : Advantages and Disadvantages of several ENC Scheme Designs

Design	Advantages	Disadvantages
Equivalent to paper chart	Easy conversion of published paper chart to ENC	Numerous cells with M_COVR CATCOV = 2. Irregular way of presenting data. Cell coverage for the same purpose at different scales. Information display irregularly.
Grid	Provides organized coverage, seamless and without overlapping for purposes Avoid the use of M_COVR attribute CATCOV = 2 Cells standardized in sizes	Increased number of production cells Unnecessary subdivisions. Geographical accidents represented in several cells of the same navigation purpose.
Exclusive ENC	Cells adapted to the geographical feature Avoid overlaps and the use of M_COVR CATCOV = 2 Flexibility of dimensions in cells. Provide information in accordance with recommended purposes	Cells not arranged symmetrically (They do not preserve dimensions)
Combination of designs	Free adaptation to meet a need	Not ideal for the same navigation purpose

Regarding this disparity, the IHO has coordinated with the Hydrographic Service of Korea on the development of a portal where the ENC coverage and complementary information of all the Regional Hydrographic Commissions are centralized and visualized, establishing itself as the only place to obtain the information. The pilot project was presented during 2018 at the meetings of the WEND and NCWG nautical cartography working groups.

- (ii) Disparity in the design of the existing schemes in the hydrographic offices, given that there is no standardized pattern for the production of ENCs in the RHCs, which indicates that most of the producing countries are doing it independently, evidenced by a lack of uniform coverage. For each RHC there is a diversity of designs (**Figure 2**), such as the Grid system, the equivalents to paper charts, adjacent rectangular cells, and the combination of systems by the same producer.
- (iii) Regarding the analysis of the ENC metadata in the RHCs, the information on the compilation scale is considered a weakness. This is due to the need to know the varied use of scales for navigation purposes in the region, which represents the application of the attribute of minimum visualization difficulty to the objects; does not guarantee a complete visualization of the coverage through ECDIS systems; and shows non-compliance with the series of scales recommended by the IHOI specifications.

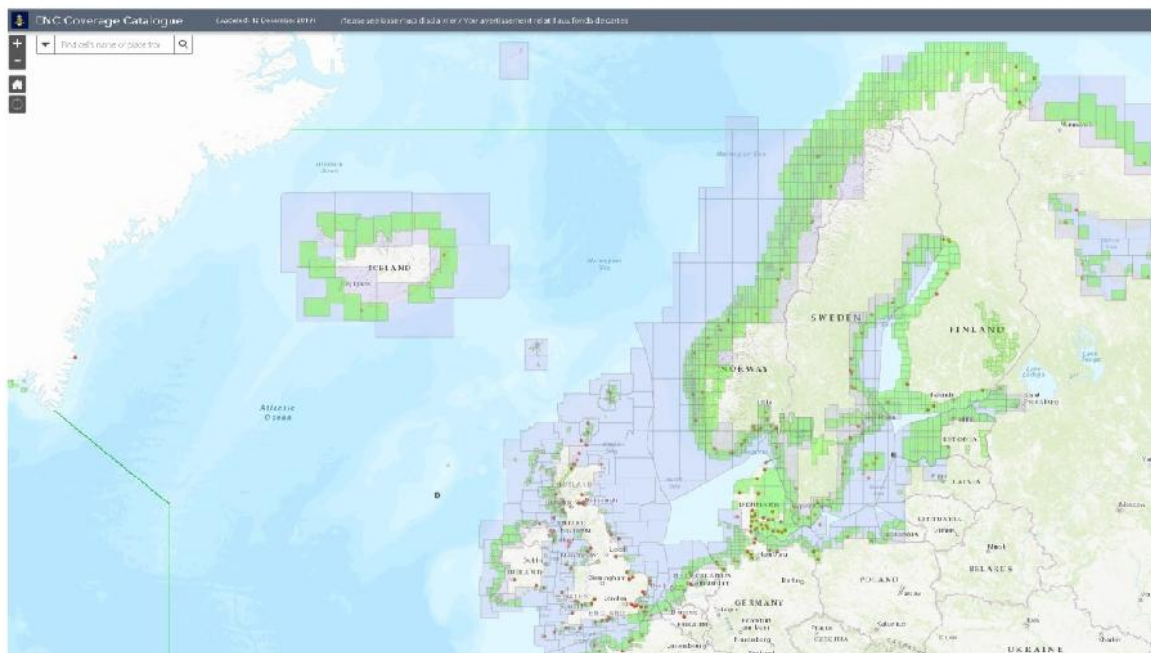


Figure 2 :Shows the diversity of designs in the same region regardless of purpose. The purple cells correspond to the Coastal navigation purpose and the green cells to the Approach purpose, showing irregular shaped designs, Grid, among others. Source: IHO online catalog of ENC coverage and availability, revised July 2021. <http://iho.maps.arcgis.com/apps/webappviewer/index.html?id=06d967702c7f4094bbc5b4f8e485b712>

(iv) In general, in all the RHCs, the dependence on the cartographic production of other countries is evident.

In the framework of uniform coverage available for the region of the MACHC, incomplete coverage is appreciated, due to the inequality in the cartographic capacities of the countries that make up the region, however, some areas are covered by cells produced by other countries. One case is that of the Cayman Islands, (**Figure 3**) ENCs from these islands are produced by NOAA for Oceanic and General purposes and by the UK Hydrographic Office for Approach and Port purposes, on the 1: 2 160 000, 1: 1 200 000, 1: 45 000 and 1: 8 000 scales respectively.

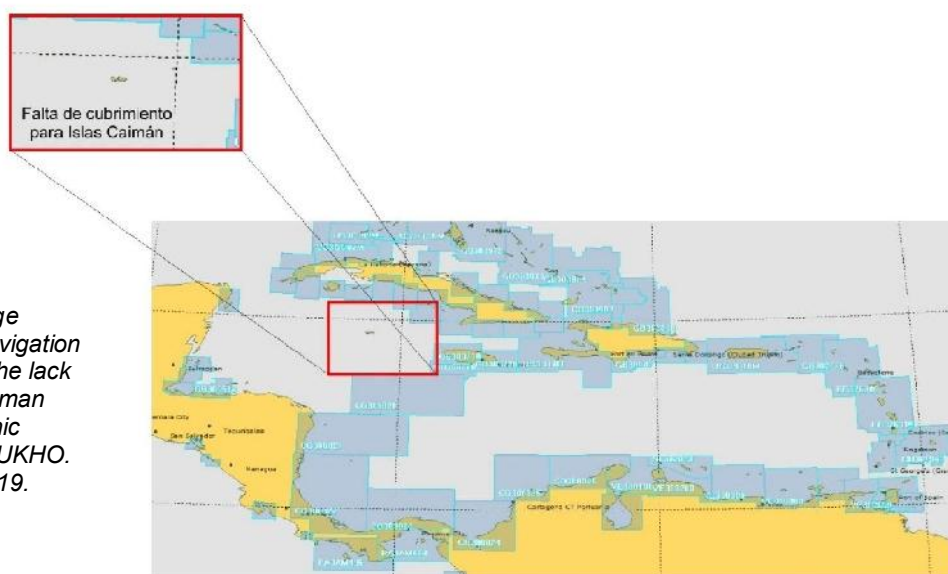


Figure 3: ENC coverage available for Coastal navigation purposes, highlighting the lack of coverage for the Cayman Islands. UK Hydrographic Office Digital Catalog - UKHO. Visited in November 2019.

- (v) Most of the countries did not adopt the international paper chart scheme for each region during production of ENC's. A specific case, the INT Region B MACHC chart scheme was analyzed, in which Colombia and Venezuela partially used the international chart scheme:

Venezuela and Colombia neighboring countries adopted the INT paper chart scheme, however, the ENC coverage for the General purpose is not continuous; in the area there is a cell captured by the UK Office, it does not use the limits of the INT scheme of the region. As shown in **Figure 4**.

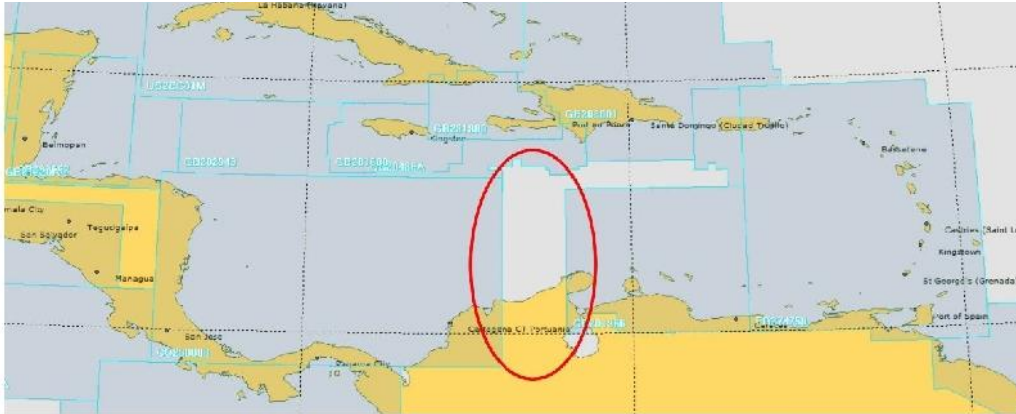


Figure 4 : In the General navigation purpose, the irregularity of the coverage of areas in charge of different producing countries is evidenced and the fissure in the cartographic coverage of ENC's is highlighted by the red oval. Source: UK Hydrographic Office digital catalog - UKHO. Consulted November 2019.

In the coastal scales, the cells present inconsistencies with respect to the adjacent depth area, where the Venezuela cell represents a depth area of 20m to 200m, and the Colombia cell shows the area with a depth range of 50m to 100m. This is the cause of the inconsistent display that is shown in the ECDIS, under certain settings, the two areas in different shades of blue.

Due to the differences between the medium-scale INT chart scheme and the Coastal use band 3 ENC coverage, in this subregion, it is important to assess whether there is adequate ENC coverage for this purpose due to the density of maritime traffic.

In addition, incomplete coverage, whether in a specific region or in bordering situations, is also due to the varied handling of the compilation and display scales for a navigation purpose, (**Figure 5**) generating uncertainty to the end user and unpredictable behavior of ECDIS.



Figure 5 : Incomplete coverage and visualization of ENC's, in the Caribbean Sea
Source: MACHC online catalog, November 2018

STRENGTHS

Currently, other countries like USA, are implementing strategies for their products such as raster charts, ENC's and paper, re-schematizing their cartographic production plans independently in a Grid system.

The dependence of cartographic production in other countries is shown as a strength, due to the increasing coverage of ports, especially with the purposes of navigation in the Bay and Approach, contributing to the security and economy of the region.

There is a recognized need by the member states of the MACHC region to harmonize ENC coverage for Coastal, General and Oceanic navigation purposes.

Finally, there is strength in the willingness of the countries to seek strategies to acquire capacities and evaluate their production, in a regional manner, considering the impacts faced by the end user (ECDIS) regarding the management of several scales and designs of ENC schemes for purposes of navigation.

5. WORK IN PROGRESS MRES WORK SUBGROUP (ENC MACHC REGIONAL SCHEME)

Faced with the large task of strengthening the management of the MACHC regarding the coverage of ENC's, evidence of the weaknesses and strengths found on the ENC designs in the regions was presented during the 20th meeting of the MACHC 2019, with special emphasis on the commission. As an initial result of research for academic purposes, the option of Regional ENC Schemes was proposed to be approved by the commission in order to unify scales, scheme origin and cell sizes for Oceanic, General and Coastal navigation purposes. (MACHC, 2019)

Standardization, in this context, refers to maintaining uniformity and consistency for the purpose of maritime safety. This requires ENC producer countries to take the right course when thinking about providing quality and safety to the end user. As a result, hydrographic offices must address the need to redefine their ENC's to achieve this objective.

The design of the adjustment scheme was socialized, presenting a solution for the study area, proposing a greater coverage with fewer cells based on the ENC coverage and the INT scheme of paper charts; always seeking to maintain contiguous, adjacent cells; and giving coverage to the ports and geographical features. Finally, it was deemed necessary to make adjustments in the Coastal scale before it is discarded because the project line focuses on harmonizing and standardizing, which would leave the solution centrally and temporarily for the MACHC regardless of the current position of the International Hydrographic Organization in achieving consistent integrity with other RHC's.

Therefore, as part of the fruitful discussion on the research, the Assembly approved the creation of the MICC - MRES (MACHC Regional ENC Scheme) working subgroup during the MACHC 20th Regional Hydrographic Conference, led by Mexico and Colombia.

The first action of MICC-MRES was the analysis of the proposal made by Colombia at the MACHC 20th Regional Hydrographic Conference of a Regional Scheme by means of a questionnaire that would capture the point of view and considerations of each country on the convenience, feasibility and the acceptability of having a regional scheme, taking into account the complexity of the needs that are required to change the scheme (technical, professional, financial resources, time, among others).

According to the feedback carried out (MACHC, 2020), opinions were divided between five countries; some supported a new scheme with the Grid system while others supported the need to adjust only the current ENC's, making the size more flexible in sectors where there are gaps under

the idea of harmonizing in terms of compilation scale with consistent application rules such as the use of SCAMIN, to ensure visualization for the ECDIS user.

The subgroup decided to start by developing options for the minor bands (Oceanic and General) and assigned actions to develop a common proposal for Grid schemes. The goal is for the producing countries to reach an agreement and start with the implementation and redesign before facing the challenge of the S-101 standard.

The United States supports the proposal to opt for regional schemes, therefore, it has provided the scheme prepared for its country (Nyberg, J. et al, 2020) as a reference for the investigation process (**Figure 6**). However, the United Kingdom continues to explore options in order to adjust the better coverage of your production globally.

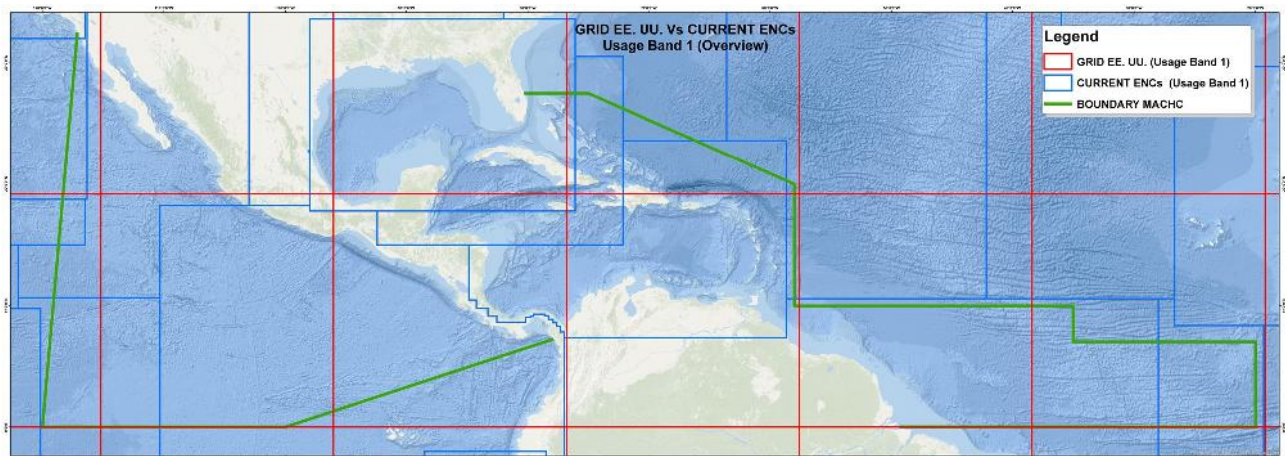


Figure 6 visualization of scheme Grid EE. UU. Vs Current ENC's in the Usage Band 1.

Through statistical analysis based on the size of current ENC's in the MACHC, the MRES subgroup has made a proposal for a Grid scheme for the Oceanic usage band (**Figure 7**), in order to jointly discuss with the Member States aspects such as origin of the Grid, cell sizes for navigation purposes and the definition of scales for harmonized production at a regional level with global influence (**Figure 8**).

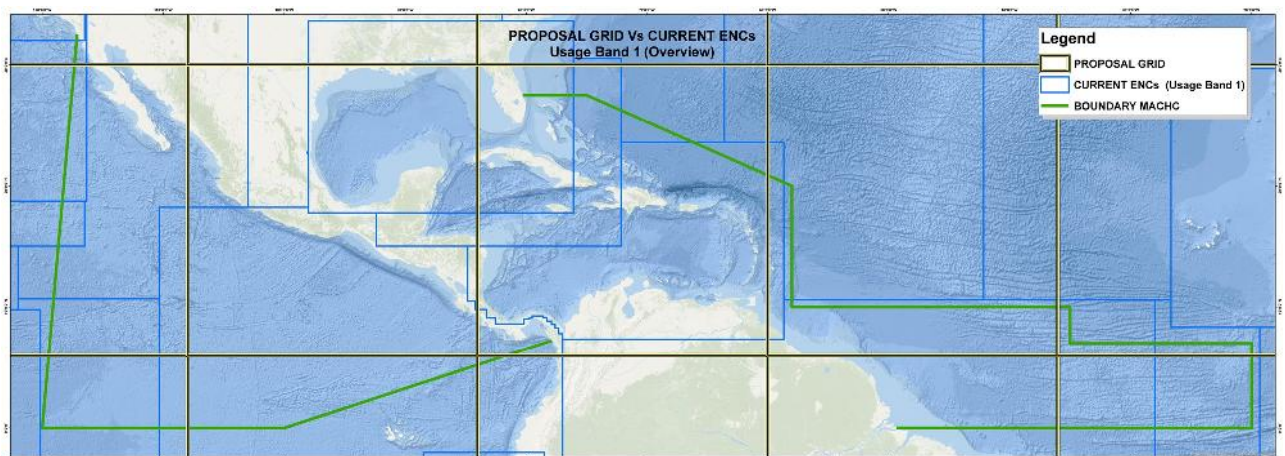


Figure 7 visualization of proposal scheme Grid. Vs Current ENC's in the Usage Band 1.

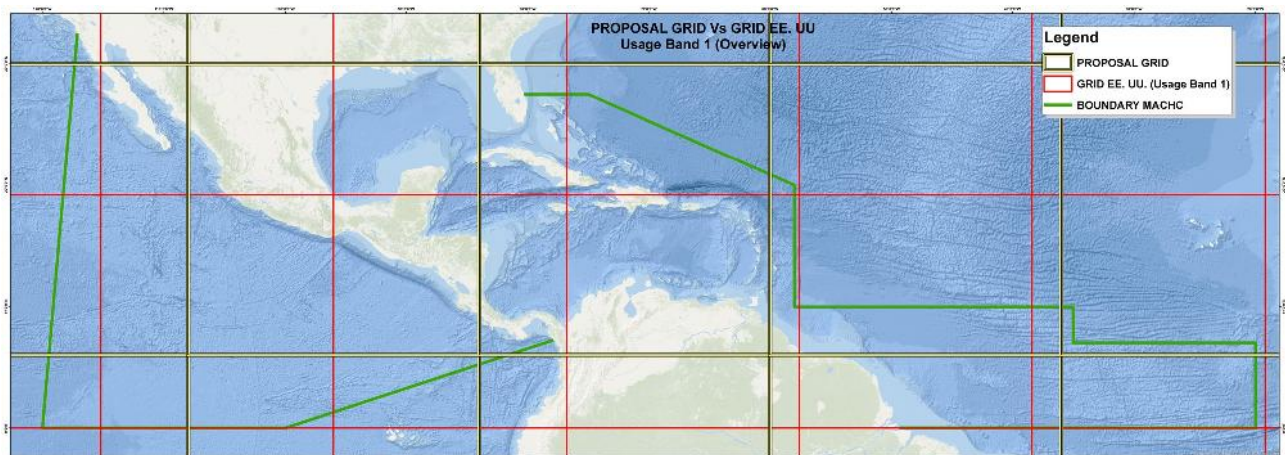


Figure 8 :Differences about sizes with designs of schemes grid for cover the current ENC's in the MACHC. Origin Grid EE.UU. 0,0; and Proposal Grid MRES -90, -180 for usage band 1.

5. DISCUSSION

The proposal to adjust the scheme is not a regular Grid system, it is a proposal to unify sizes based on the current coverage and sizes of INT Paper charts, in order to reduce the number of cells to maintain. Considering the differences between the production capacities in the countries of the region, an alternative was proposed to reduce the impact on production.

The design of the proposed regular Grid system would be ideal for a seamless global scheme; therefore, it is necessary for the IHO to approve the scales, the sizes for the cells for navigation purposes and the origin of the grid established by the Subgroup of MRES work in order to avoid transferring the problems of the past. It must be taken into account that some nations have already migrated a gridded ENC scheme, independently presenting a difference between the sizes of the ENC's.

Gridded ENC's can support future solutions for automated paper chart production from ENC's. Some countries like Australia, Germany, Japan, Korea have partially migrated their ENC's to regular grid designs (USCHC, 2021); for the United States, NOAA is currently transforming their ENC scheme.

6. RECOMMENDATIONS

- The working subgroup should conduct further research and discussion on a possible ENC grid for the MACHC. It would be useful to know the opinions of more of the member states, and to get producers to agree on the uniform grid that allows an optimal and comprehensive schema.
- Establish ENC schemes at the level of standardized RHC's for the purposes of Oceanic, General and Coastal navigation that are approved and adopted by the region in order to guarantee the end user a consistent coverage, avoiding continuing the production of ENC's independently.
- When designing the cell scheme, overlaps and gaps should be avoided for coverage in the same navigation purpose, which allows greater consistency between products, increases the confidence of navigators, optimizing the performance and use of ECDIS.
- Every port must be mapped regardless of the size or activity it carries out for the sake of security.

- Unify, among the producing countries of the region, the information corresponding to the range of compilation scales for navigation purposes recommended by IHO Circular 047 of 2004, in order to facilitate the application of the minimum display scale attribute (SCAMIN) in subsequent ENC's and ensure continuous mapping via ECDIS (IHO, 2004).
- In order to provide uniform and quality coverage to the end user, it is recommended that neighboring countries establish agreements or memoranda of understanding between producing countries in order to authorize shared publication of data.
- Carrying out bathymetric surveys complying with IHO standards is one of the fundamental aspects to have the adequate information that must be represented in the ENC's.

7. CONCLUSIONS

The IHO has long suggested a gridded approach to an ENC scheme, as typified by its many publications on the subject. During an IHO meeting in Singapore, this uniform grid approach was formally proposed to the hydrography community. (HSSC, 2009). However, after a decade there is still a debate on the problem of overlaps and gaps.

This research and analysis concludes that the proposal of a new Grid scheme will avoid overlaps and gaps, which mainly benefits the ECDIS user by having a uniform display increasing maritime safety.

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9. AUTHORS BIOGRAPHIES

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