Article

Assigning S-57 SCAMIN Attributes for Archipelagic Seas: Eastern Adriatic Coast Experience

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Abstract

The production of Electronic Navigational Charts (ENC) at the Hydrographic Institute of the Republic of Croatia (HIRC) started in 2001 covering the area of the northern Adriatic. At the time when ENC production started for the Middle Adriatic, which is a typical example of an archipelagic sea, it was concluded that implementation of the currently known methodologies for on-line generalisation using SCAMIN attributes led to apparent density of objects on the computer screen. Therefore, on the basis of the Canadian method, a new methodology of using SCAMIN attributes was suggested to be applied to a wider area of the Šibenik harbour.

Résumé

La production de cartes électroniques de navigation (ENC) au Service hydrographique de la République croate (HIRC) a débuté en 2001 avec la couverture de la zone Adriatique Nord. Lorsque la production d'ENC a commencé pour le centre de l'Adriatique, qui est un exemple caractéristique de mer archipélagique, on est arrivé à la conclusion selon laquelle la mise en œuvre des méthodes actuellement connues pour la généralisation en ligne en utilisant l'attribut SCAMIN conduisait à une densité apparente d'objets sur l'écran informatique. Par conséquent, à partir de la méthode canadienne, il a été suggéré qu'une nouvelle méthode d'utilisation de l'attribut SCAMIN devait être appliquée à une zone plus étendue que celle du port de Šibenik.

Resumen

La producción de Cartas Electrónicas de Navegación (ENCs) en el Instituto Hidrográfico de la República de Croacia (HIRC) empezó en el año 2001, cubriendo la zona del Adriático septentrional. Cuando la producción de ENCs empezó para el Adriático Medio, que es un ejemplo típico de un mar archipelágico, se concluyó que la implementación de las metodologías actualmente conocidas para una generalización "on-line" utilizando los atributos SCAMIN llevó a una densidad aparente de objetos en la pantalla del ordenador. Así pues, basándose en el método Canadiense, se sugirió que se aplicase una nueva metodología del uso de los atributos SCAMIN a una zona mayor del Puerto de Šibenik.

1. Introduction

The Austro-Hungarian Navy was among the first in Europe to establish a Hydrographic Office for the east Adriatic coast. Established in Trieste in 1860, it was among the first institutions in Europe to have uninterrupted hydrographic activities lasting to the present day (except during WWI and WWII). The first systematic and complete hydrographic survey of the Adriatic Sea was carried out from 1866 to 1869. On the basis of this survey, in 1872 the Hydrographic Office issued 43 navigational charts for different purposes (1 overview chart, 4 general, 30 coastal, and 8 harbour and berthing charts). The pilot "Segelhandbuch für das Adriatische Meer" was published in 1892 (Kozličić and Duplančić Leder, 2003).

In the past, the Hydrographic Office often changed its name and location along the Adriatic coast, from Trieste to Pula, Tivat and Dubrovnik. In 1929, the Hydrographic Office moved to Split, which is situated in the middle of the Adriatic coast. The first pilot written in Croatian was issued in 1952.

In 1991, the Croatian Government established the Hydrographic Institute of the Republic of Croatia (HIRC) as a national institution responsible for all hydrographic activities on the east coast of the Adriatic Sea under the authority of Croatia. As a result of continued hydrographic activities, to the present day HIRC issued about 100 navigational charts of different scales and purposes and 30 nautical publications.

A new era in the production and use of navigational charts occurred with ENCs. In 2001, the HIRC began the production of an ENC covering the area of the northern Adriatic in conjunction with an international pilot project, the Virtual Regional Electronic Navigational Chart (VRENC). The project was proposed by the Italian Hydrographic Office within the framework of Mediterranean and Black Seas Hydrographic Commission (MBSHC). The International Maritime Academy in Trieste was the coordinator of the project, while C-map Italy and Hydroservice AS were technical consultants and training providers (Altamura, 2003).

The VRENC pilot project was completed in 2003 when ENCs were quality controlled and validated by the HIRC. At that time, there was no need to use SCAMIN attributes (on-line generalisation) since the North Adriatic is less indented, less demanding and complicated for navigation than other parts of the Adriatic Sea.

After the end of the pilot project, the HIRC started its own production of ENC data. However, when ENC production captured the area of the Middle Adriatic, which is an archipelagic sea, it was concluded that the problem of on-line generalisation had to be solved by using SCAMIN attributes. By studying the world literature on this topic, it was found that only two methods of on-line generalisation using SCAMIN attributes, the German (7Cs) and the Canadian ones, were available (Bisset and Fowle, 2003a).

The purpose of this paper is to describe the methodology used to assign SCAMIN attribute values for ENC data in the archipelagic sea area of the Croatian part of the Adriatic Sea.

2. Specific Features of the Adriatic Sea

2.1. The Adriatic Sea As an Archipelagic Sea

According to the United Nations Convention on the Law of the Sea, Part IV - Article 46 (http://www.

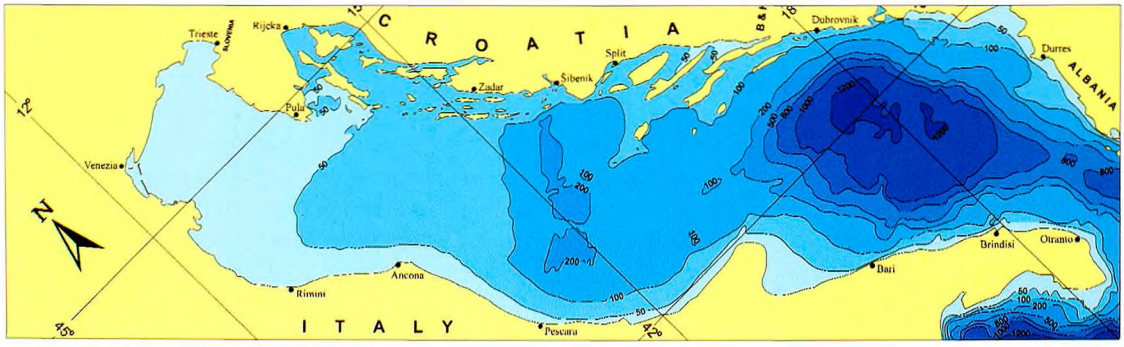

Figure 1: Bathymetryic map of the Adriatic Sea.

un.org/), the term of Archipelagic State is defined as:

(a) State constituted wholly by one or more archipelagos and may include other islands.
(b) "Archipelago" means a group of islands, including parts of islands, interconnecting waters and other natural features which are so closely interrelated that such islands, waters and other natural features form an intrinsic geographical, economic and political entity, or which have been historically regarded as such.

The Croatian islands area (Figure 1) makes the second largest archipelago in the Mediterranean. The Adriatic Sea with 79 islands, 525 islets, and 642 rocks and rocks awash (1,246 total) along 4,398km of insular coastline length and 6,278km of coastline length (Duplančić Leder et al., 2000). Countless straits, passages and other areas dangerous for navigation along the Croatian part of the east coast of the Adriatic Sea cause this area to be an exceptionally complex navigational entity. Furthermore, with such a large number of islands, Croatia boasts one of the most indented coasts in the world. In addition to Greece, it is the most indented coast line in the Mediterranean. For these reasons, it can be concluded that the Croatian part of the Adriatic Sea belongs to the so-called archipelagic seas.

Such a difficult and complex navigational area therefore demands a rigid regime of navigation. This is possible to achieve by using high-quality navigational charts and nautical publications.

Since archipelagic areas cause clutter on an ECDIS display, it is necessary to apply on-line generalisation. One of the possible methods is using SCAMIN attributes values.

2.2. Other Specific Features of the Croatian Part of Adriatic Sea

In the Adriatic Sea, tides are of mixed type, with pronounced inequality in height. In syzygy tides are semidiurnal and in quadrature they are diurnal. During syzygy mean, tidal amplitudes are 0.23m, 0.29m, 0.48m and 0.68m for Dubrovnik, Zadar, Rovinj and Trieste respectively (Leder, 2004). It can be concluded that tides have influence on the safety of navigation only in the North Adriatic.
Currents have little influence on the safety of navigation in the open sea area. Mean current speeds in the open sea are about 0.5 knots. Only in certain conditions, particularly in narrow passages and near river mouths currents may reach a speed of 4 knots (Leder, 2004).

The Adriatic Sea is a warm sea. Freezing of the sea surface is a rare occurrence. It may occur only in areas with fresh water during extremely cold winters (Leder, 2004).

In the eastern part of the Adriatic coast there are no navigable rivers with the exception of the Neretva mouth (a shallow area navigable only by small boats), which makes ECDIS display very special for that area.

In the coastal area there are no mangroves, salt marshes or swamps that make navigation and berthing difficult.

3. Coverage of Croatian Coast with Charts

3.1. Coverage with Paper Charts

The Adriatic Sea is adequately covered with charts for all navigational purposes , except for the largest scale charts, approach, harbour and berthing charts. Navigational charts issued by the HIRC are presented in this paper.

Overview charts of the Adriatic Sea used by the HIRC are 108 (INT 301) and 109 (INT 302) at the scale of 1:2,500,000 showing the eastern and western parts of the Mediterranean Sea, as well as charts 101 and 102 at the scale of 1:800,000 showing the Adriatic and Ionian Seas.

The Adriatic Sea is best covered with general charts. Three series of charts are currently used: 150, 160 and 170 series at the scale of 1:200,000 covering the Adriatic and Ionian Seas (20 charts), INT 3410, 3412 and 3414 series at the scale of 1:250,000 (3 charts) and 300 series at the scale of 1:300,000 (7 charts).

Coastal charts of the 100 series cover the whole eastern Adriatic coast from Italian harbour Trieste to the Albanian harbour Durrës with 16 charts (from 100-15 to 100-30) at a scale of 1:100,000.

Three approach charts of the 50 series (21 charts) at the scales of 1:50,000 and 1:55,000 were

Navigational Purpose	Scale Range	Available Compilation Scales	Matching Scale Ranges
Overview	<1:400,000	400,000 and smaller	96 - 200 NM
General	1:180,000 – 1:399,999	350,000 / 700,000	24 – 48 NM
Coastal	1:90,000 – 1:179,999	90,000 / 180,000	6 NM - 12 NM
Approach	1:22,000 – 1:89,999	22,000 / 45,000	1.5 NM - 3 NM
Harbour	1:4,000 – 1:21,999	4,000 / 8,000 / 12,000	0.25 NM - 0.5 - 0.75 NM
Berthing	> 1:4,000	3,999 and larger	< 0.25 NM

Table 1: Assignment of navigational purposes to scale ranges – a new proposal for archipelago seas based on suggestion of Bisset and Fowle (2003a).

issued (50-3, 50-4, 50-20) and several harbour and berthing charts at different scales.

3.2. Coverage with ENCs

During the VRENC project, 9 ENCs covering the area of the northern Adriatic were completed as follows:

- 5 coastal charts at a scale of 1:100,000 (100-15, 100-16, 100-17, 100-18, 100-19) (Figure 2).
- 2 approach charts at a scale of 1:55,000 (50-3, 50-4).
- 2 harbour charts at a scale of 1:10,000 and 1:30,000 (15-Rijeka and harbour Pula).

As a data source for the production of ENCs, the HIRC uses recently issued paper navigational charts. Following quality control and data verification, by the end of 2003 HIRC started its own production of ENCs using two modules: Editor and Inspector of the Hydroservice software package dKart (http://www.hydroservice.no). ENC data are maintained monthly. Two new coastal ENCs, HR10020 and HR10021 (Figure 2), and several harbour and berthing ENCs were produced.

ENCs produced by the HIRC are not in use yet, because they have not passed the verification test on the ship bridge and HIRC does not have the contract with distribution centres yet.

About two thirds of the Adriatic Sea is covered with coastal ENCs, but in general the Adriatic is poorly covered with ENCs for other navigational purposes.

According to the suggestion of IC-ENC «Improving ENC consistency» (Bisset and Fowle, 2003a), the HIRC assigns each ENC cell to the navigational purpose based on the ENC compilation scale and determined by the ranges as shown in Table 1 (Bisset and Fowle, 2003a; IHO, 2004; TSMAD, 2004). Table 1 was made according to available navigational charts issued by the HIRC, adapted to an archipelagic sea such as the Adriatic.

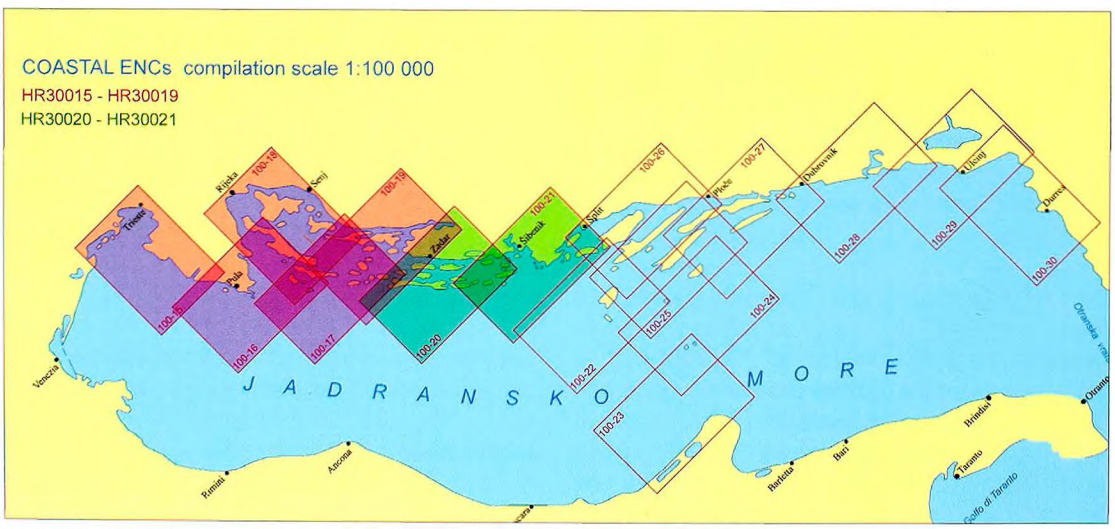

Figure 2: Coverage of the Croatian part of the Adriatic Sea with coastal ENCs.

4. SCAMIN Attributes and Experiences of Other Countries

As it is known from the references that SCAMIN is the IHO S-57 attribute designed to provide the means for controlling an on-line generalisation in the ECDIS (Vachon, 2003). By definition it is the minimum scale at which the object may be used (e.g., for an ECDIS presentation). In order to optimise the performance and clarity of the ENC data it is strongly recommended that SCAMIN is used (IHO S-57 Appendix B1 Annex A, 2000).

Reported experiences of other countries like Australia, Italy, Germany, Portugal and Finland in using SCAMIN attributes are very diverse (Hudson 2000, D'Aquino 2003, Festerding 2002; Jonas and Melles 2003, Pais 2001, Tuurnala and Laitakari 1999). However, reported by Bisset and Fowle (2003a), most of the hydrographic offices mainly use one or other of two methods:

- Semi-automatic method proposed by an expert group from the Canadian Hydrographic Service (Vachon, 2003) and
- automatic method suggested and initiated by the expert group of SevenCs, a German producer of the software package for ENC cell creation (Ulrich et al., 2003; SevenCs, 2003).

The German (7Cs) and Canadian (CHS) methods of assigning SCAMIN attribute values are based on their own experiences. In analysing these methods we determined that neither is entirely suitable for archipelagic sea areas (e.g., eastern Adriatic, Croatia, Greece, Sweden, Finland, etc.). We propose that a modified method be used.

5. Assigning SCAMIN Attributes for the East Adriatic Coast and Other Archipelagic Seas

The generalisation method for selecting objects ENC data contents does not differ from the same method applied for compiling paper charts. However, paper charts are different from ENC cells in terms of representation of data, different resolution - 1,000 dpi versus 100 dpi, and way of usage. Among available methods, we took the Canadian method of on-line generalisation and then modified and adjusted it further for an archipelagic sea such as the Middle Adriatic.

SCAMIN factor		GEO OBJECT CLASSES
0	Skin of the Earth Objects	DEPARE, DRGARE, FLODOC, HULKES, LNDARE, PONTON, UNSARE
	Meta and Collection Objects	M_ACCY, M_COVR, M_CSCL, M_NPUB, M_NSYS, M_QUAL, M_SDAT, M_SREL, M_VDAT, C_AGGR, C_ASSO
	S-52 Display Base Objects	BCNCAR, BCNLAT, BCNSPP, BRIDGE, BOYCAR, BOYINB, BOYISD, BOYLAT, BOYSAW, BOYSPP, CBLOHD, CANALS, COALNE, DOCARE, DWRTCL DWRTPT, ISTZNE, MAGVAR, MORFAC, OBSTRN, OFSPLF, OILBAR, PIPOHD, PRCARE, RDOCAL, RCRTCL, RCTLPT, SLCONS, TSELNE, TSSBND, TSSCRS, TSSLPT, TSSRON, TSEZNE, TWRTPT
6	General	ADMARE, CTNARE, FSHZNE, PILBOP, RESARE, STSLNE, TESARE, UWTROC, TWRTPT, WRECKS
4	Coastal	ACHARE, ACHBRT, BCNISD, BCNSAW, BUAARE, CBLARE, CBLSUBCURENT, DEPCNT, FERYRT, HRBARE, LIGHTS, LNDMRK, NAVLNE, OSPARE, PIPARE, PIPSOL, RTPBCN, SLCONS, SOUNDG, TOPMAR,
2	Approach	AIRARE, BUISGL, FAIRWY, FSHFAC, MARCUL, LAKARE, LNDELV, LNDRGN, RADRFL, RAILWY, RIVERS, ROADWY, RUNWAY, SBDARE, SILTNK, SISTAT, SISTAW, TUNNEL
1,5	Harbour Berthing	BERTHS, CEMTRY, CHKPNT, CTRPNT, CRANES, CUSZNE, DAYMAR, DISMAR, DRYDOC, DYKCON, FOGSIG, FORSTC, FNCLNE, HRBFAC, PILPNT, PRDARE, RADSTA, RDOSTA, SEAARE, SLOTOP, SLOGRD, SMCFAC, VEGATN,

Table 2: Assignment of Geo and Meta object classes according to ENC navigational purposes – a new proposal for archipelago seas.

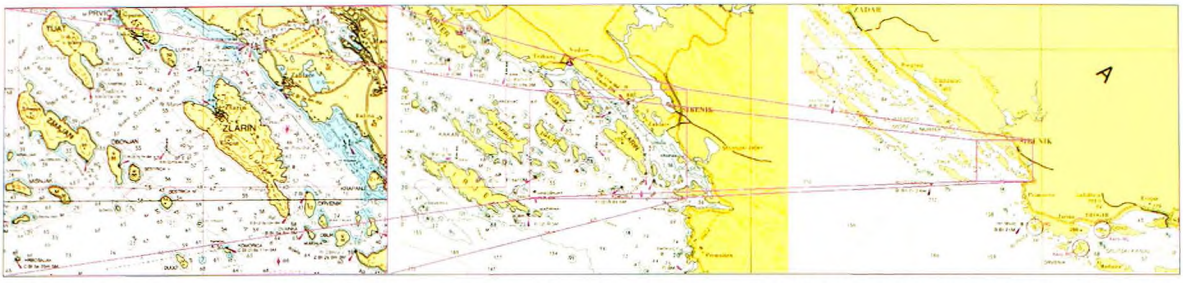

Figure 3: Wider area of approach to Šibenik harbour on different scale charts: a) 1:100,000 (left), b) 1:250,000 (in middle) and c) 1:800,000 (right).

Table 2 presents a new method (called the Croatian method) of cartographic rules for applying SCAMIN object coding based on the tradition of compiling charts in the HIRC. According to navigational purposes, objects appearing on ENCs are classified into five groups following the recommendations presented in the IC-ENC (Bisset and Fowle, 2003a, b). Each group includes objects that should be used in the particular navigational purpose. The objects on harbour and berthing charts belong to the same group that is in compliance with the traditional production of charts at the HIRC.

On the basis of the Canadian formula for calculating SCAMIN values (Vachon, 2003), a new formula was introduced:

$$SCAMIN\_value = (CSCL * SCAMIN\_factor) * 0{,}9 \quad (1)$$

where CSCL is compilation scale of ENC cell.

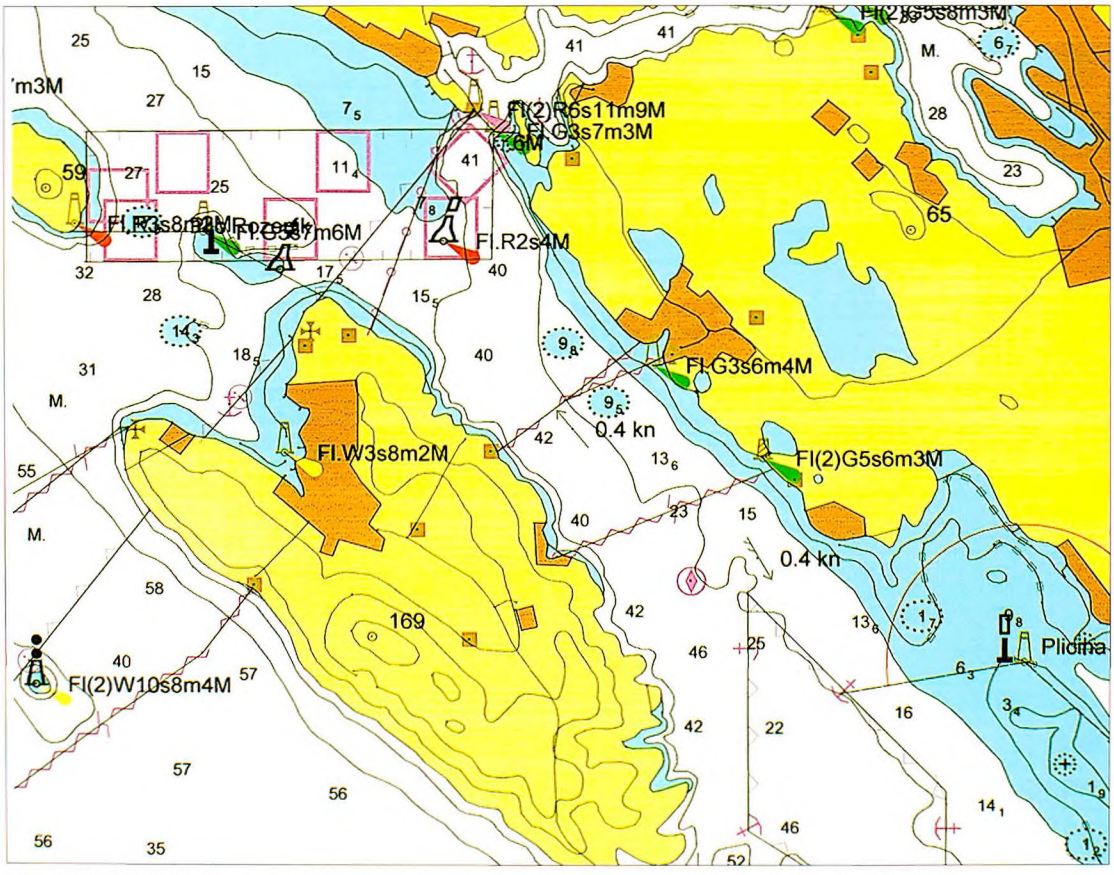

Figure 4: ENC HR31021 with wider area of approach to Šibenik harbour, compilation scale 1:50,000.

There are three classes of objects which do not have a SCAMIN values (Table 2):

- S-57 Group 1 objects (skin of the earth objects),
- Objects defined by S-52 to be "Display Base" objects (objects that the mariner cannot remove from ECDIS display),
- S-57 Meta objects (information about the ENC).

There are two object groups defined for ENC: Group 1 (skin of the earth) and Group 2 for all other geo feature objects. Each area covered by a Meta object M_COVR with CATCOV = 1 must be totally covered by a set of Geo objects of type area that do not overlap each other (the skin of the earth). These objects make up Group 1 (DEPARE, DRGARE, FLODOC, HULKES, LNDARE, PONTON, UNSARE) which must always be displayed. Therefore, SCAMIN must not be used with Group1 objects (IHO S-57 Appendix B1, 2000).

We also except some Geo object classes that do not exist or have negligible significance on the Adriatic Sea, as well as phenomena or conditions which do not exist or have negligible significance on the Adriatic Sea. These objects are irrelevant for the presentation on ENCs of the Adriatic Sea according to IHO standard S-57.

It should be pointed out that a method of simplification and generalisation could be used, not just removing all objects of a certain type from ECDIS display (Bisset and Fowle, 2003a). SCAMIN coding rules are not mandatory, thus some of the objects may be considered as exceptions. For example, if applying SCAMIN to the object class SOUNDG, more critical soundings should remain visible longer, rather than all soundings disappearing at the same moment (Bisset and Fowle, 2003a). So, object LIGHTS can be divided into several categories, for example harbour lights, lights and lighthouses (Figure 6). A similar partition may be applied to DEPCNT. Any strategy for assigning values to the attribute SCAMIN needs to consider the navigational significance of individual objects together with the clarity of the data when viewed at the ECDIS display scales available (Bisset and Fowle, 2003a).

6. Results

Generalisation of data by choosing objects is shown in the example of a wider area of approach to the Šibenik harbour (see Figures 3, 4, 5, 6, 7 and 8). Wider area of approach to the Šibenik har-

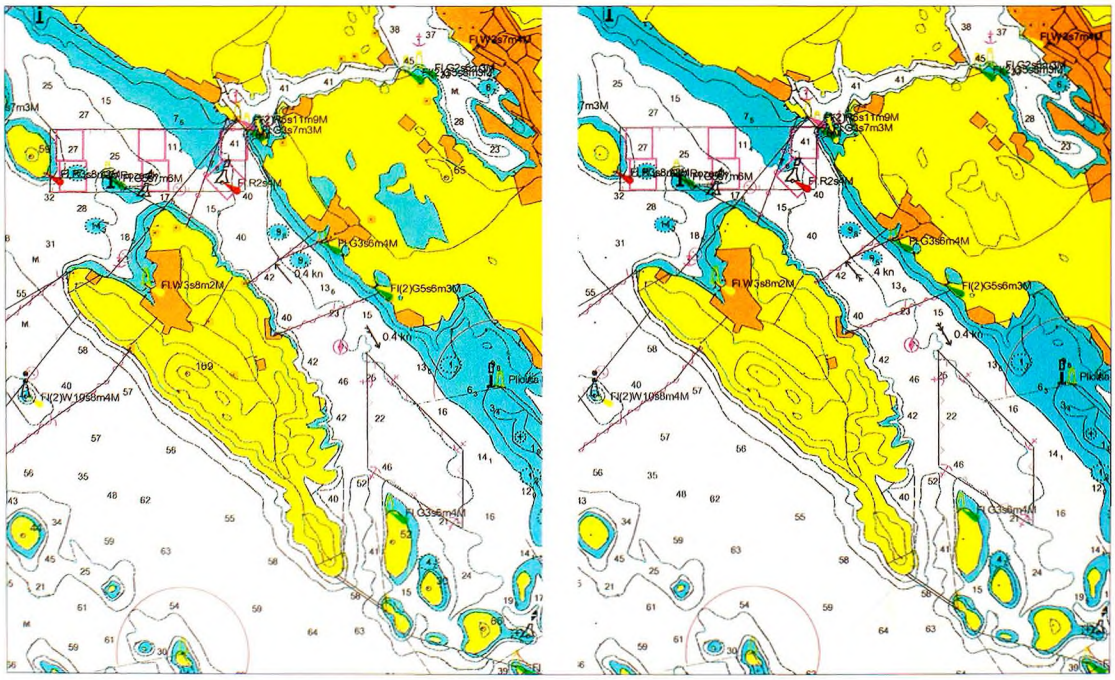

Figure 5: Wider area of approach to Šibenik harbour (scale 1:100,000): a) without SCAMIN coding (left) b) with Croatian SCAMIN coding method (right).

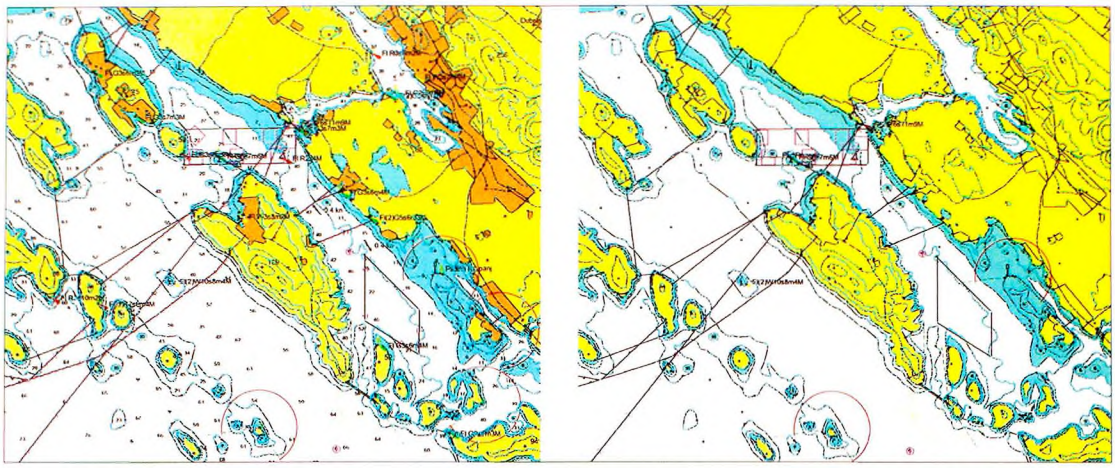

Figure 6: Wider area of approach to Šibenik harbour (scale 1:200,000): a) without SCAMIN coding (left) b with Croatian SCAMIN coding method (right).

bour is one of the most demanding navigational areas. It is a very good example of clutter on the ECDIS display.

Figure 3 shows a wider area of approach to Šibenik harbour as presented on the HIRC paper charts of different scales and navigational purposes. On the left there is a coastal paper chart 100-21 at a scale of 1:100,000, in the middle a general chart INT3412 at the scale of 1:250,000, and on the right an overview chart 101 at a scale of 1:800,000.

Figure 4 shows a part of ENC HR31021 presenting a wider area of approach to the Šibenik harbour, which is a good example of clutter on the screen crowded by many objects. The ENC cell was compiled according to the paper coastal chart 100-21 Šibenik-Split (Figure 3, left side) at a scale of 1:100,000. By comparison of the left side of Figure

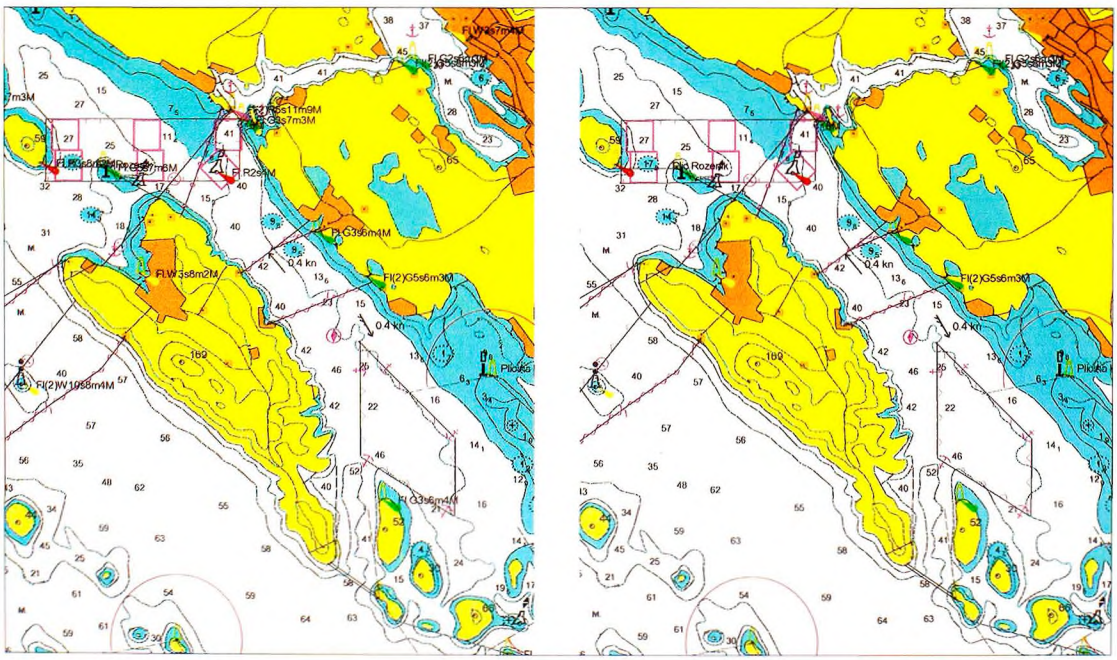

Figure 7: Wider area of approach to Šibenik harbour (scale 1:100,000): a) Croatian method (left) b) Canadian method (right).

3 with Figure 4, it can be concluded that this area is better presented by setting the compilation scale twice the chart scale (scale 1:50,000). Chart data in this area are very dense and setting the compilation scale to be less than twice the source scale results in too much screen clutter. It should be pointed out that similar areas are very common in the Croatian part of the Adriatic coast.

In Figures 5, 6, 7 and 8, zooming out of compilation scale at ENC HR31021 is presented. Figures 5 and 6 depict Croatian method assigning S-57 SCAMIN attributes values, while Figures 7 and 8 show the results of Croatian and Canadian methods.

The left side of Figure 5 shows a wider area of approach to Šibenik harbour at a scale of 1:100,000 without using SCAMIN attributes, while the same area is shown on the right side of Figure 5 having applied SCAMIN attributes coding. Some objects disappeared from the screen (BUISGL, LAKARE, LNDELV, LNDRGN, RAILWY, ROADWY, SBDARE) as suggested in Table 2. It can be noted that there is no significant difference between the left and right side of Figure 5 although some objects disappeared from the screen. Moreover, screen display of this area is not so crowded and suitable for navigational use.

The left side of Figure 6 shows ENC HR31021 at a scale of 1:200,000 without using SCAMIN attributes and consequently the screen display is very crowded. The right side shows the suggested method of usage of SCAMIN attributes as in Table 2. According to the suggestions presented in Table 2 the objects disappearing from the screen are: ACHARE, BCNISD, CBLSUB, CTNARE, CURRENT, DEPCNT, LNDMRK, LIGHTS, PIPSOL. By comparison of the left and right side of Figure 6 it is shown that there are less objects on the screen depicted on the right. Generally, by using SCAMIN attributes the clutter is reduced, screen display is readable with all navigational information for the route planning purposes.

The proposed (Croatian) method of on-line generalisation of ENC data contents presents a simplification of the Canadian method and its adjustment to the Croatian tradition in the compilation of paper navigational charts. This method ensures a better reduction of clutter on an ECDIS display and serves as an input to the ENC display optimisation, showing specific features of an archipelagic sea on the eastern side of the Adriatic coast. Specific quality of the Croatian method is a smaller number of SCAMIN factor values (Table 2) than in Canadian method, which is sufficient for an on-line generalisation of ENC content.

Comparison of the Croatian and Canadian methods applied on ENC HR31021 at a scale of 1:100,000 is shown in Figure 7. It can be seen that the left and right side of Figure 7 are almost identical. The difference is in the fact that by applying the Croatian method Geo object classes with SCAMIN factor 2 disappear from the screen at a scale of 1:90,000. If the Canadian method is used, this happens at a scale of 1:100,000.

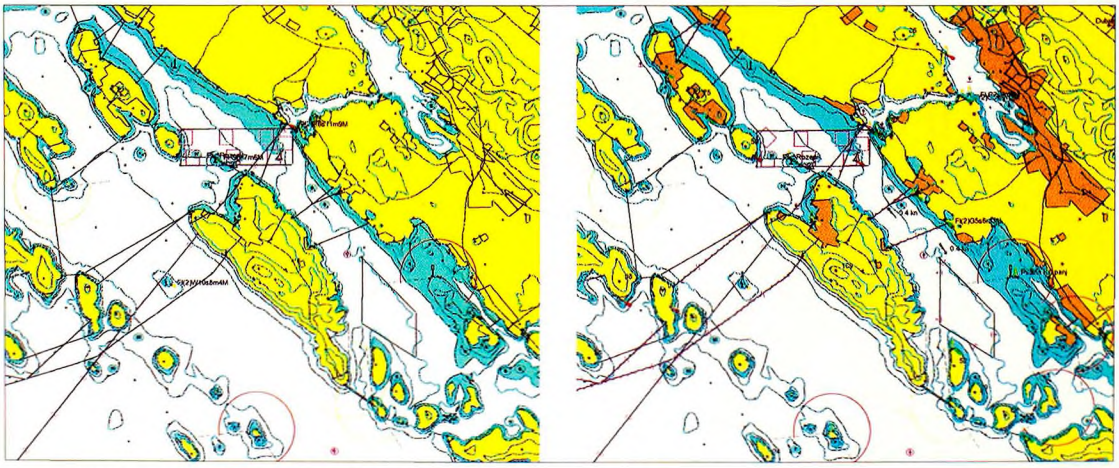

Figure 8: Wider area of approach to Šibenik harbour (scale 1:200,000): a) Croatian method (left) b) Canadian method (right).

The left and right side of Figure 8 shows a comparison of the Croatian and Canadian methods on the same ENC cell at a scale of 1:200,000. At this scale the difference between the two methods is obvious. Applying the Croatian method a larger number of Geo object classes disappeared from the screen (from a scale of 1:180,000), giving better results in reducing clutter display for an archipelagic area.

Summary

The Croatian part of the east coast of the Adriatic Sea is a very complex navigation area and can be considered as an archipelagic sea. During ENC production of the Middle Adriatic area, object density on the computer screen was apparent. In order to reduce clutter or density of objects on the display, a compilation scale twice the chart scale was used. This was based on IHO guidelines and IC-ENC recommendation for "Improving ENC Consistency". Cartographic rules for applying SCAMIN attribute coding for on-line generalisation were developed by using a modified Canadian method. This effectively reduced the level of clutter on ECDIS display for the Adriatic Sea area. All ENC objects are classified into five groups according to their navigational purpose and each group includes objects that should be used for the particular navigational purpose. The objects on harbour and berthing charts belong to the same group. The SCAMIN value for the particular group was calculated by a new formula.

Our method is in compliance with the traditional production of charts at the Hydrographic Institute of the Republic of Croatia and was presented on a wider area of approach to the Šibenik harbour. With slight modifications, this method could be applied to other archipelagic sea areas.

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