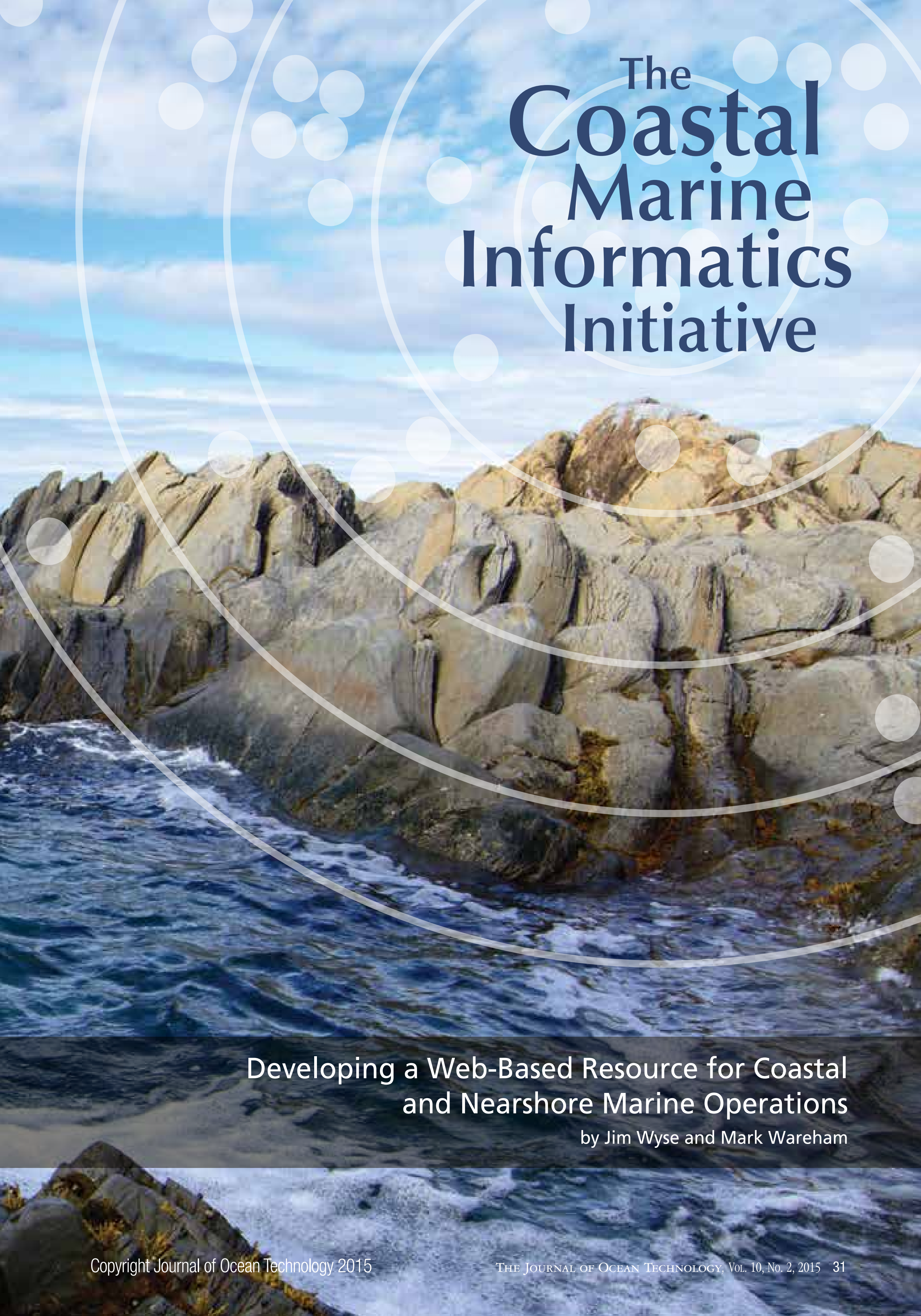

The Coastal Marine Informatics Initiative

Developing a Web-Based Resource for Coastal and Nearshore Marine Operations

by Jim Wyse and Mark Wareham

Throughout its entire history the marine sector has relied heavily on information. The breadth of informatic sources of interest to mariners is extensive: hydrographical, meteorological, navigational, ecological, biological, even cultural and political. In all categories, considerable value is placed on valid information derived from reliable sources of knowledge about highly localized conditions and circumstances. Although much has changed over centuries with respect to the variety of sources and depth of information as well as the means by which information is generated and communicated, much has not. Information media fragmentation (some digital, many not), information processing disintegration (disparate collection, transformation, and communication mechanisms), as well as information management deficiencies (in data creation, maintenance, retrieval, and retirement) all remain major challenges in providing a reliable and useable information resource to support marine sector activities. The Coastal Marine Informatics (CMI) Initiative seeks to address the issues of fragmentation, disintegration, and deficient management across informatic sources through the development of a web-based resource facilitating the consolidation, communication and customization of information useful to mariners.

Any examination of coastal and nearshore marine operations readily imports dozens of relevant informatic sources presenting themselves in a variety of formats and dating from widely disparate time periods. Information from the relatively distant past is often juxtaposed with that from the immediate present: it would not be unusual to find the coastal mariner in concurrent use of hydrographic survey data derived from the British Admiralty surveys of the 1700s as well as localized weather phenomena information published in an Environment Canada marine weather compendium in the early 1990s along with meteorological data of 30 seconds ago from SmartAtlantic's Internet-connected oceanographic buoys. Other sources abound: navigation aids, marine and inland weather forecasts, sailing directions, hydrographic chart coverage limits and availability, mooring placements, harbour and dockage locations, tidal station proximities, location-specific cruising guide reports, marine radio broadcast and communications stations, marine service centres, along with many others. One of the least formalized but far from least important informatic sources on coastal conditions is that of the highly localized, experiential knowledge acquired by those active in nearshore activities. An important task of the CMI Initiative is the creation of facilities to capture this knowledge, validate its content, and integrate it with other sources in a way readily usable by coastal mariners. Figure 1 shows the product of a rudimentary web-based CMI facility that reports localized hydrographic chart anomalies and invites others to update, extend, confirm, or even refute what has been reported. In what follows, the approach taken by the CMI Initiative to develop a multi-sourced, integrated, web-based information resource to support coastal and nearshore marine activities is described and discussed.

The *Newfoundland Spirit*: An *i*-Prox Case Study

With the perspective of a coastal mariner in mind, let's examine a selection of links to multiple informatic sources available through the current web-based CMI resource for use with the *Newfoundland Spirit* commercial fishing enterprise. The *Newfoundland Spirit* is a multi-species, 20-metre vessel based in Newstead-Comfort Cove, Notre Dame Bay, on the island of Newfoundland. In pursuit of shrimp, crab, turbot and various pelagic species (herring, mackerel and capelin), her primary harvesting area is Newfoundland's northeast coast extending seaward to distances reaching 200 nm. She also fishes other grounds ranging from as far south as the Northern Grand Banks to as far north as areas east of Groswater Bay in Labrador. Figure 2a shows a webpage for the *Newfoundland Spirit* with a link (at centre-left) to its "spatial directory" information. Spatial directory (SD) information consists of

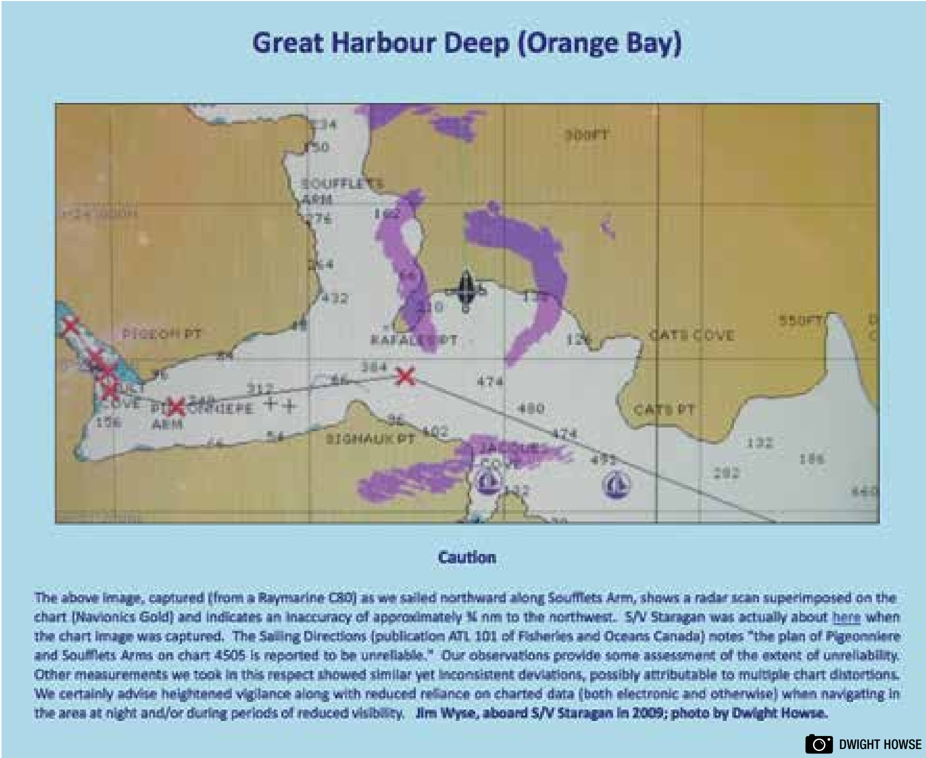

Figure 1: An illustration of CMI's facility to capture and validate the local knowledge of coastal mariners.

Figure 2a: *Newfoundland Spirit*'s web page showing its spatial directory (SD) link.

location-qualified links to specifically themed web-based resources. When combined with a vessel's geographical position, or geo-position, SD information may be presented in a radar-like range and direction pattern centred on a vessel's position. The placement of each SD link corresponds to its relative geo-position in a vessel's proximity. The radar-like "blips" form an informatic proximity or "*i*-Prox" of links to information from and/or about physical locations in the vessel's proximity. Figure 2b shows an "operational *i*-Prox" of six SD links to information used to support immediate vessel operations; Figure 2c shows a "resource *i*-Prox" of several hundred links currently within the *Newfoundland Spirit*'s selected *i*-Prox range. All the links in the resource *i*-Prox (and many more when a greater range is selected) are available for optional inclusion in the *Newfoundland Spirit*'s operational *i*-Prox.

Links (in the form of "blips" in the resource *i*-Prox) originate from multiple SDs with each SD indexing a distinct collection of localized marine knowledge. A review of the six links annotated in the *i*-Prox of Figure 2b will readily identify some collections in this respect. Blips for two marine weather stations (MWS) appear in the *Newfoundland Spirit*'s *i*-Prox: MWS LaScie and MWS Twillingate. These also appear (without annotation) in Figure 2c's resource *i*-Prox; however, they originate with the spatial directory underlying the *i*-Prox of marine weather stations seen in Figure 3. *Newfoundland Spirit*'s *i*-Prox also includes a link to small craft harbour information for Comfort Cove, a link into the Fisheries and Oceans Canada's (FOC) web-available collection of harbour facilities information indexed by the SD underlying the *i*-Prox seen in Figure 4. Another blip links to SmartAtlantic's Internet-connected oceanographic buoy in the Bay of Exploits. This link accesses one of SmartAtlantic's array of oceanographic buoys whose web pages are indexed by the SD underlying the *i*-Prox seen in Figure 5. The blip for "Great Harbour Deep – Chart Anomaly" derives from an SD entry similar to those underlying the *i*-Proxs seen in Figures 2, 3, 4, and 5. The content in this case is mariner-reported chart anomalies such as that seen in Figure 1. The remaining blip in the *Newfoundland Spirit*'s operational *i*-Prox locates and links to the wreck site of the *S.S. Clyde*. This blip was created, and is thus "owned," by the *Newfoundland Spirit*'s spatial directory. If it is designated as a shared link by *Newfoundland Spirit*'s SD owner, it becomes part of CMI's web-based information resource and is thence available to other SDs in the same way that the SDs for marine weather stations, harbour information, oceanographic buoys, and chart anomalies were available for inclusion in the *Newfoundland Spirit*'s SD. This exemplifies a key CMI information management concept: each SD contributes to, and draws from, a mutually shareable coastal marine informatics resource.

Spatial Directory (SD) versus Informatic Proximity (*i*-Prox)

SDs contain location-qualified links. For example, the spatial directory entries for an SD of two stations reporting marine weather conditions would be retained as a CMI resource in a form similar to the following:

Station	Latitude	Longitude	URL to Web Resource
1606	49.9656	-55.5866	http://w . . . stationID=wag
1607	49.6875	-54.8012	http://w . . . stationID=wdo

When a vessel's geo-position is selected or acquired (e.g., 49.4038, -54.8557) then SD entries may be transformed into *i*-Prox form (as follows) and rendered to appear as seen in the *i*-Prox shown in Figure 2b.

Blip ID	Range	Direction	Blip Hyperlink
2	44.2 nm	320°	http://w . . . stationID=wag
5	17.2 nm	007°	http://w . . . stationID=wdo

The CMI Resource and Related Functionality: Design Tenets

Five design tenets underlie CMI development initiatives: (1) link shareability, (2) non-impactual indexation, (3) spatial projection compatibility, (4) proximity generation timeliness, and (5) localized knowledge acquisition. The first tenet "link shareability"

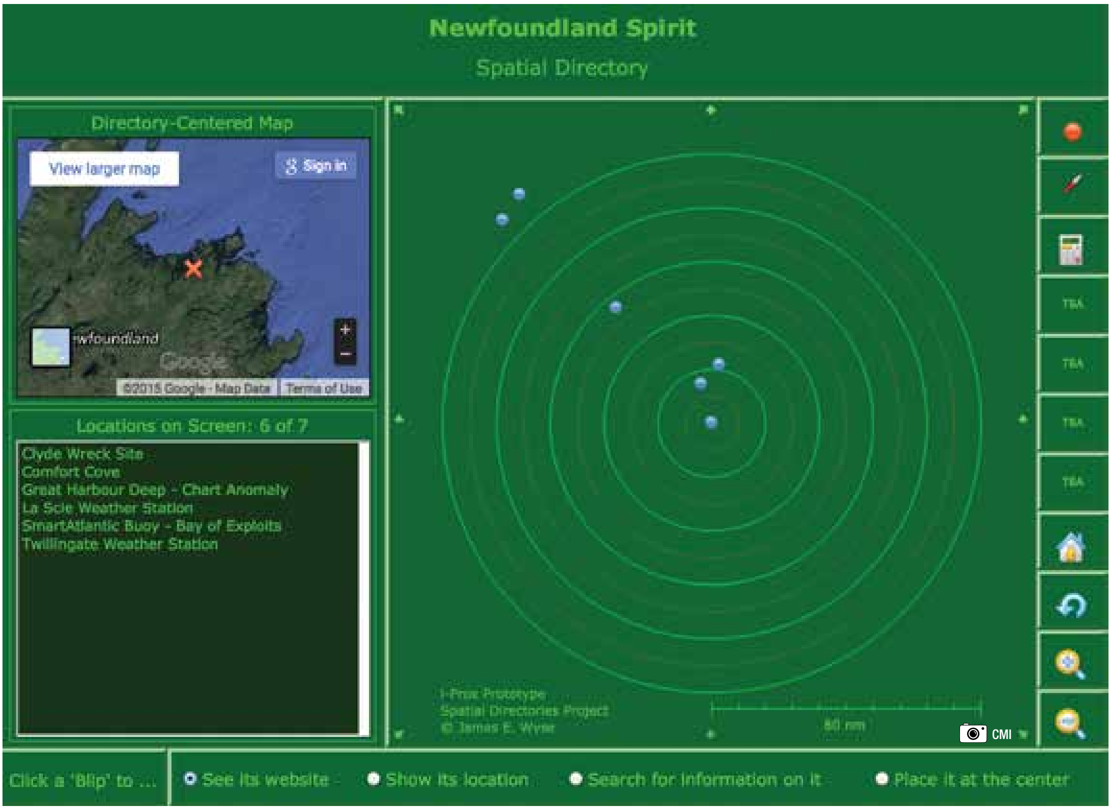

Figure 2b: The vessel's operational *i*-Prox (informatic proximity).

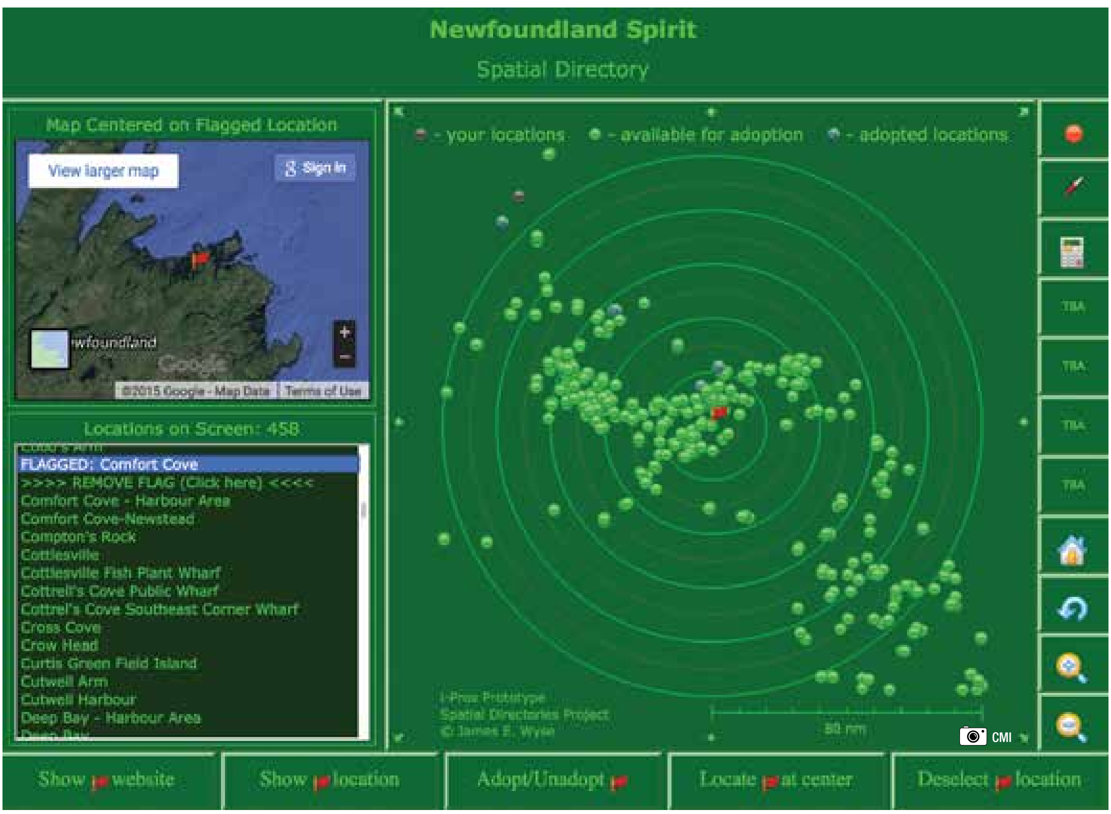

Figure 2c: An *i*-Prox of the resource SD at the 80 nm range.

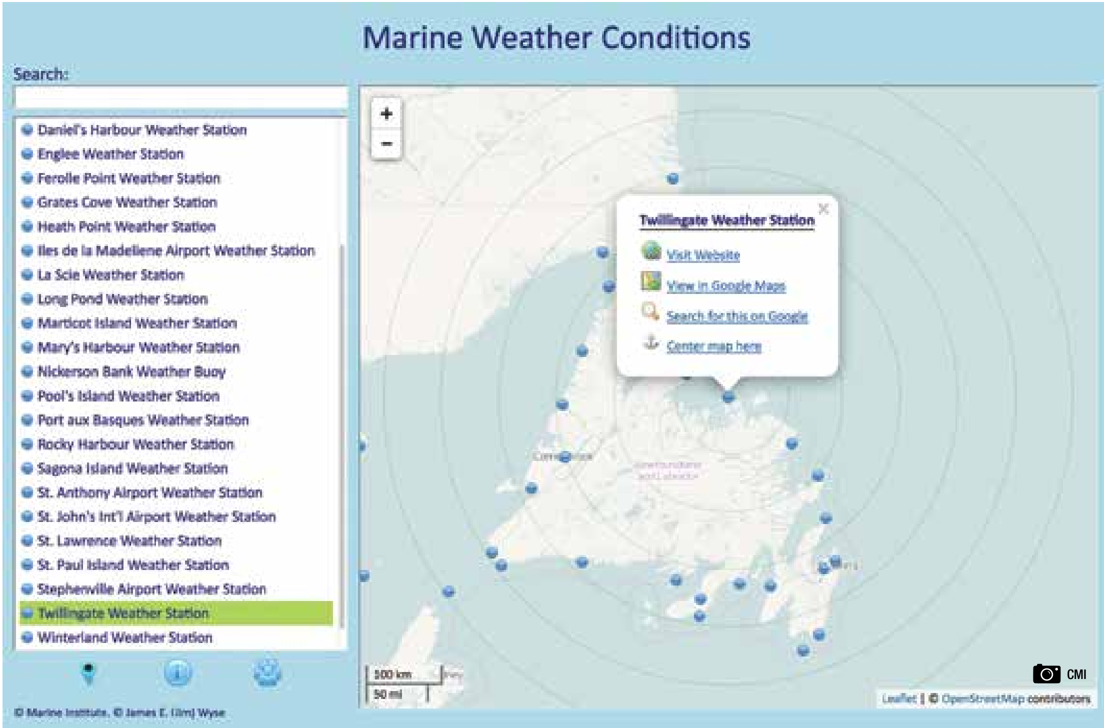

Figure 3a: An *i*-Prox of the spatial directory for marine weather stations (MWS).

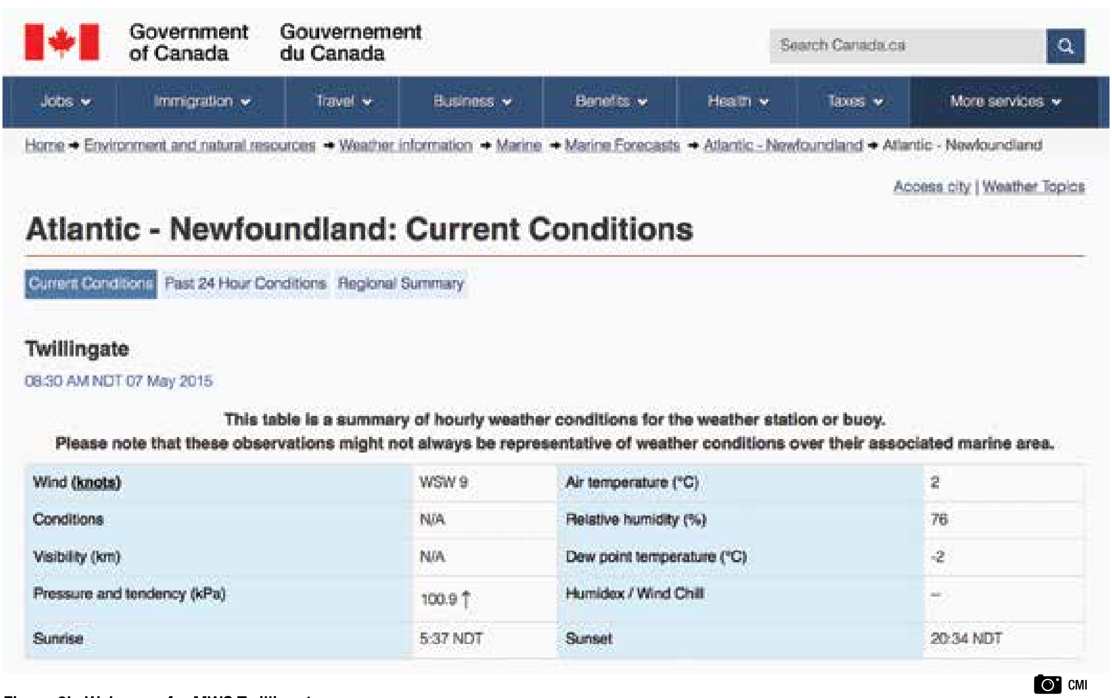

Figure 3b: Web page for MWS Twillingate.

Figure 4a: An *i*-Prox of the spatial directory of Fisheries and Oceans Canada Small Craft Harbours (SCH).

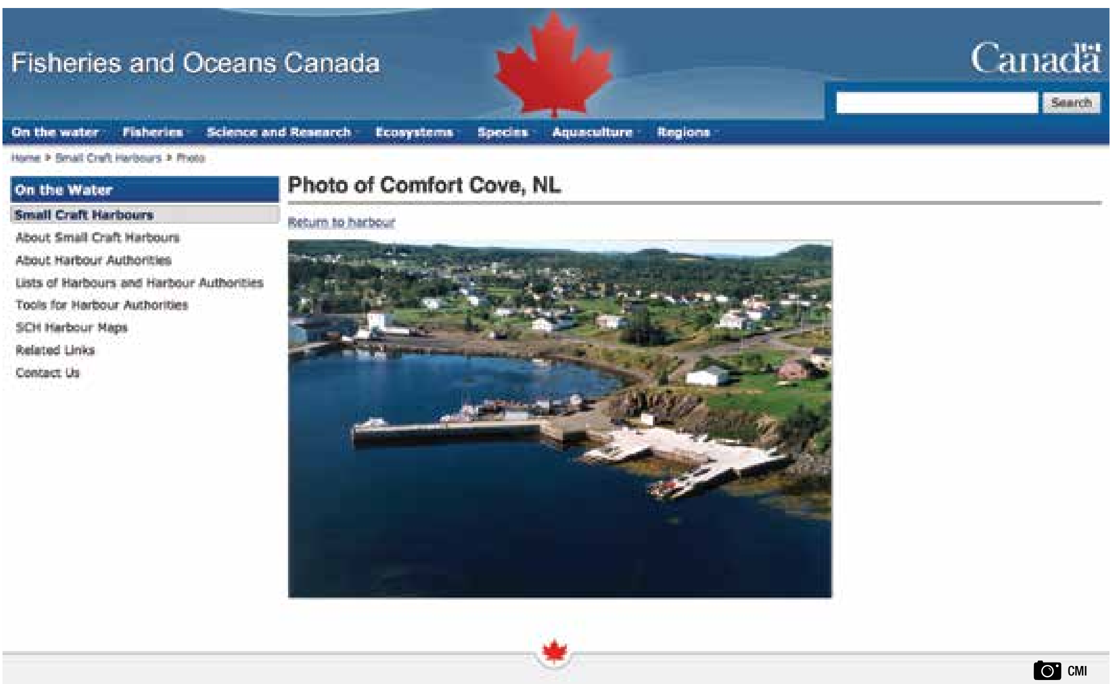

Figure 4b: Web page for SCH Comfort Cove.

between and among spatial directories enables the expansion, validation, and dissemination of marine knowledge along with its customization to the operational needs of coastal mariners. The foregoing discussion of the *Newfoundland Spirit*'s SD application illustrates and emphasizes the centrality of link shareability to CMI resource development and dissemination.

The second design tenet "non-impactual indexation" is one that respects and accommodates the operational independence of informatic sources to collect and communicate their respective bodies of knowledge without any impact attributable to link entries in a spatial directory or blip appearances in an informatic proximity. The web site for marine weather stations is completely unaware of the spatial directory in Figure 3a, as is the case for the web site for FOC's Small Craft Harbours with respect to the SD in Figure 4a as well as the web site for SmartAtlantic's oceanographic buoys and the SD in Figure 5a. In all three instances, CMI functionality indexes but does not impact the web site content of each informatic source.

The third design tenet "spatial projection compatibility" refers to the validity of juxtaposing informatic proximity (*i*-Prox) links derived from SD entries both across and within informatic sources. This issue essentially arises from the use of differing coordinate system datums in the determination of the latitude and longitude values that qualify SD entries. The WGS84 (World Geodetic System 1984) datum is widely used; however, dozens of other datum references remain in active use and if employed for coordinate determination could potentially yield *i*-Prox content with significant positional distortion. In most instances, distortions in this respect will be immaterial to proximity content validity; however, there are informatic sources (e.g., the List of Lights, Buoys, and Fog Signals) that use multiple datum references (e.g., NAD-27, NAD-83) within the same source. This could also be the case when a single spatial directory is constituted of entries with coordinate values taken by different methods: some extracted from web-based maps, some acquired by GPS, some taken from hydrographic charts, and other methods, etc. There will generally be some measure of spatial projection incompatibility in *i*-Prox creation; the issue is whether its extent is sufficient to comprise *i*-Prox content.

The fourth design tenet "proximity generation timeliness" refers to the rapidity with which an *i*-Prox is materialized from the CMI data resource. It seems counterintuitive that the creation of web pages such as those seen in Figures 2b, 3a, 4a, and 5a would import an issue beyond those typically salient in web page creation. However, materialization of an informatic proximity is conceptually equivalent to the "k-point Nearest Neighbour" (kNN) problem, i.e., the problem of finding the k locations in a large collection of locations that are nearest a chosen point. In the *i*-Prox seen in Figure 2b, the five (k=5) links nearest the *Newfoundland Spirit*'s position had to be found among all the 1,000+ locations contained in the CMI resource. The kNN problem is well known in computational geometry and an extensive variety of kNN solutions have been proposed; however, many solutions are not amendable to the fundamental CRUD functions of information management (creation, retrieval, updating, and deletion) and all methods exhibit solution times that are positively related to the total number of locations within which the k nearest must be found. The "unCRUD-able" kNN solutions are not feasible since CMI functionality must include information management capabilities. The "CRUD-able" solutions are compromised by the positive relationship between total CMI locations and k location search time since this relationship implies that proximity generation times degrade as the CMI data resource increases in size, i.e., as it becomes richer and more valuable to the coastal mariner. This presents a challenge to CMI functionality development; however, potential solutions are receiving research attention and results hold considerable promise that a useable level of proximity

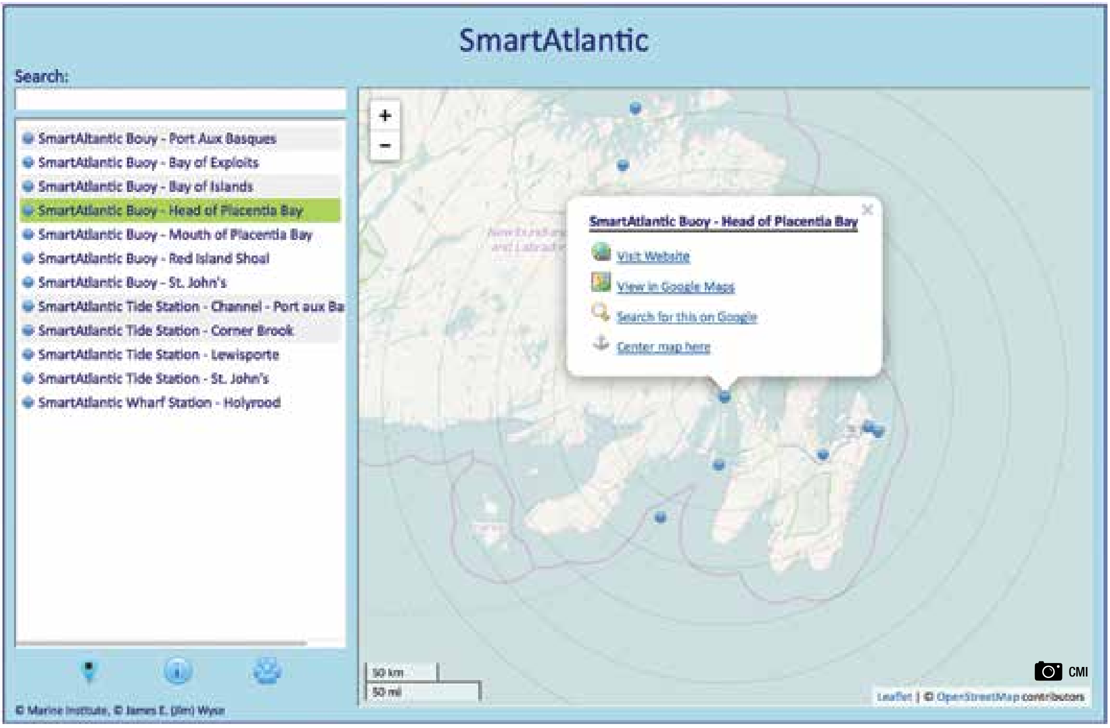

Figure 5a: An *i*-Prox for the spatial directory of SmartAtlantic oceanographic buoys (SOB).

Figure 5b: Web page for SOB St. John's.

generation timeliness can be realized in the face of an expanding CMI resource.

The fifth design tenet "localized knowledge acquisition" addresses one the essay's key opening assertions: coastal mariners place considerable value on information about highly localized marine-related conditions and circumstances. All information, even when recently published and/or posted to the web, is necessarily out-of-date. Knowledge arising from local observations is usually the

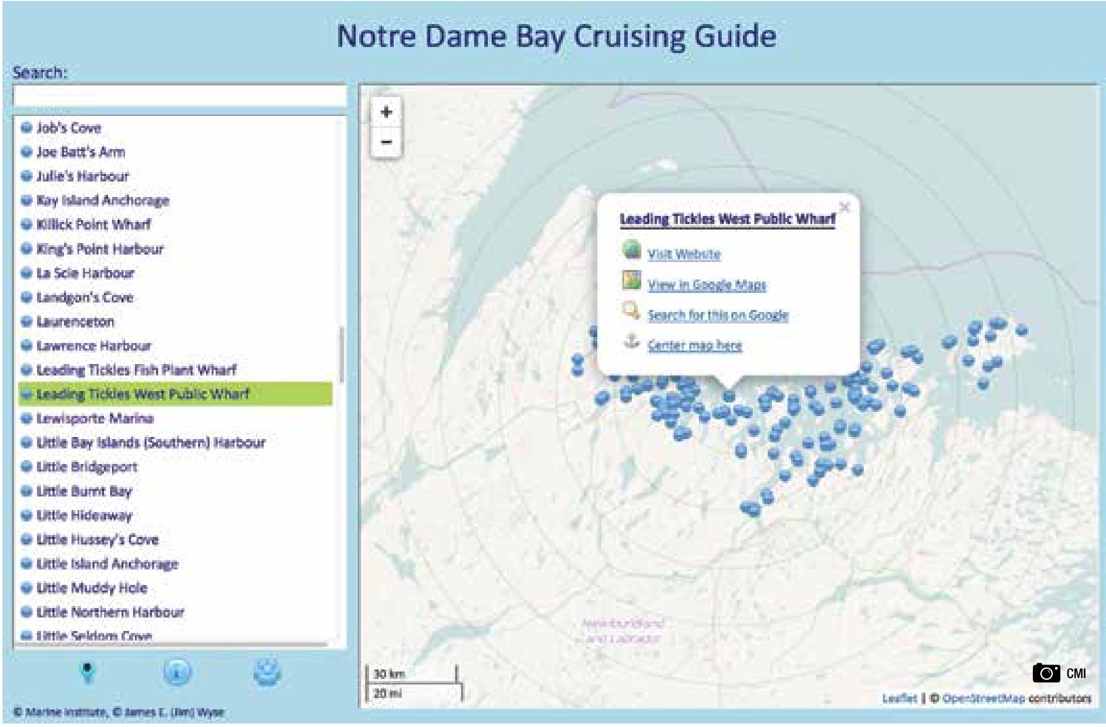

Figure 6a: An *i*-Prox of the spatial directory for the Notre Dame Bay Cruising Guide.

only practical means of making/keeping it current. The phrase "local knowledge" appears ubiquitously in various publications (e.g., official sailing directions, etc.) intended for the coastal mariner; however, it actually alludes to "gaps" in the information the source provides ("mariners are advised that local knowledge is required to enter the harbour at night and/or under conditions of reduced visibility") and implicitly recognizes the navigational benefits of localized observations. The acquisition of localized knowledge is currently facilitated by CMI functionality in two ways: (1) by creating themed spatial directories such as that underlying the *i*-Prox seen in Figure 5 for SmartAtlantic's oceanographic buoys (with a further example in this respect described in the next section) and (2) by soliciting commentary (as seen for the chart anomaly in Figure 1) from coastal mariners on web site content. While these facilitate local knowledge acquisition at two levels (the directory-level and the link-level), more functionality in respect of this design tenet will be implemented to make it easier and more inviting to contribute local knowledge of coastal marine conditions and circumstances.

CMI Notre Dame Bay: Expanding the Coastal Marine Informatics Resource

A recent CMI resource expansion project saw the creation of a spatial directory indexing information on 173 coastal marine locations within the confines of Newfoundland's Notre Dame Bay. The primary informatic source for the project was a collection of aerial photographs, chart segments, and descriptive textual material on selected harbours and anchorages throughout the Bay that had been published in print form as the *Notre Dame Bay Cruising Guide*. Although the collection was in digital form, it had not been ported to the web. So with the collection's eventual inclusion as a CMI resource in mind, the project had two major thrusts: (1) establishing a web presence that positioned the collection as a CMI informatic source and doing so in a manner that supported non-impactual indexation by a independent CMI spatial directory and (2) spatializing the collection's content by populating an SD with shareable link entries for the 173 locations. The first resulted in a web site through which corrections, revisions, and additions could be made and local knowledge could be acquired;

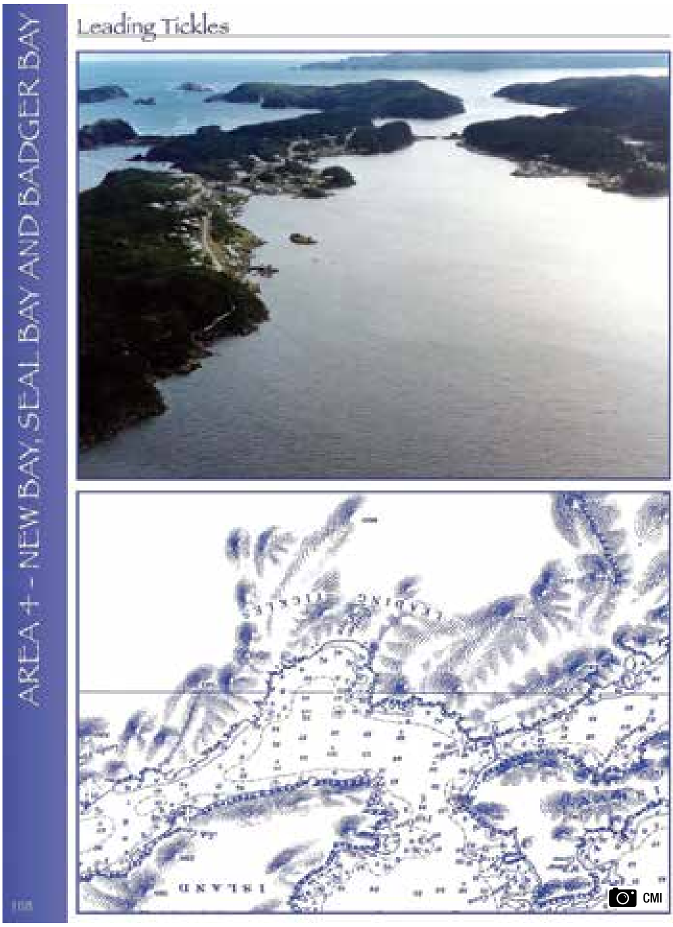

Figure 6b: Web page Leading Tickles.

the second expanded and enriched the CMI resource available to marine interests such the *Newfoundland Spirit* fishing enterprise. Figure 6a shows an *i*-Prox derived from the 173 SD entries extracted from locational information in the *Cruising Guide* while Figure 6b shows a web site linked to one of the *i*-Prox blips.

The CMI Initiative: A Development Agenda
Given the current state of the CMI resource and related functionality, it seems appropriate that further development efforts be directed toward four areas: (1) expanding and enriching the CMI resource through the creation of spatial directories indexing additional web-based informatic sources of use/interest to coastal mariners (e.g., those for navigational aids, inland forecasts for coastal communities, tidal stations, marine radio stations, mooring locations, iceberg movements, AIS-transponding marine traffic, among others), (2) populating existing but sparsely resourced spatial directories (the SD for Hydrographic Chart Anomalies, an entry of which indexes the web page seen in Figure 1, would be an instance in this respect), (3) evaluating and evolving a method of proximity generation that effectively addresses the inherent retrieval time degradation in current proximity generation approaches, and (4) accommodating non-web-available (and often copyrighted) informatic sources (examples include the various sailing direction publications by Fisheries and Oceans Canada, the Cruising Club of America's *Cruising Guide to Newfoundland*, among others).

The content of an informatic source that would be the subject of the last agenda area would generally not, for commercial reasons, be made available to coastal mariners through any web-based facility including that for the CMI resource. However, CMI could include spatial directories which "index the index" to alert coastal mariners about the existence of the content, the location to which it is relevant, and the source from which it could be acquired. Figure 7 shows an *i*-Prox (7a) and a blip web page (7b) illustrating how indexing the index would work. The topic/theme of the SD from which the *i*-Prox is derived is "Hydrographic Chart Vertices" and the *i*-Prox blips are links to the northwest, northeast, southeast, and southwest limits of Canadian Hydrographic Service Chart 4841. Three other blips appear within the confines of the chart's vertices for the (arbitrarily chosen) northwest vertex of each of 4841's three chartlet insets. Figure 7b shows the web page linked to an *i*-Prox blip for Chart 4841's Argentia inset, a web page showing not only an image of the inset but also

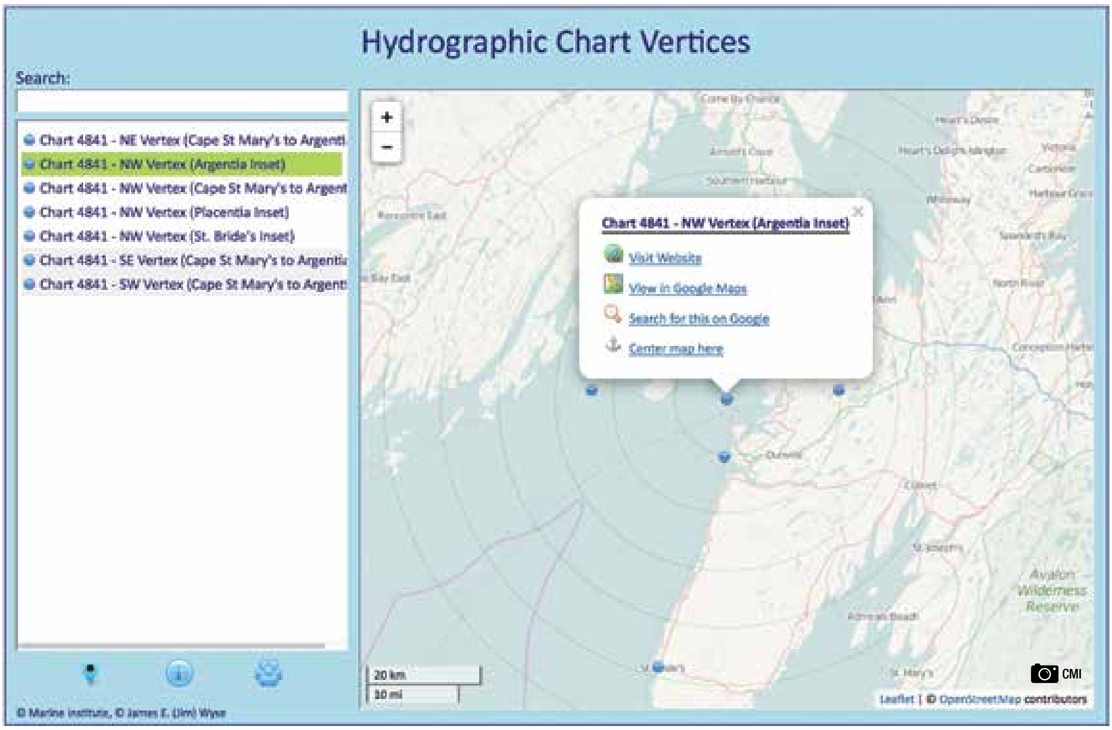

Figure 7a: An *i*-Prox for the spatial directory of Hydrographic Chart Vertices.

Figure 7b: Web page for Chart 4841's Argentia inset.

providing the functionality for acquiring the chart. Two purposes are served by the *i*-Prox of Hydrographic Chart Vertices: (1) chart coverage and availability (illustrated by the foregoing Chart 4841 example) and (2) the points where the coverage of one chart ends and another begins, information often valued by coastal mariners who are aware of the legal requirement that vessels must carry and consult paper charts for the areas in which they navigate. Let's conclude with the thought that perhaps the *Newfoundland Spirit*'s navigator would value the Hydrographic Chart Vertices SD's coverage being extended to all the coastal areas in which the vessel operates.

Acknowledgment
The authors wish to gratefully acknowledge the cooperation and assistance of the following individuals and groups: Jack Greenham for allowing the authors to use the *Newfoundland Spirit* fishing enterprise as an illustrative *i*-Prox application; Derek Bennett, Director of Recreation and Tourism at the Town of Lewisporte, and Brian Pike, President of the Lewisporte and Area Chamber of Commerce, for their support of the CMI Notre Dame Bay project along with Fred Dalley, Peter Watkins, and Jody Woolfrey who enthusiastically shared their extensive local knowledge of various locations throughout Notre Dame Bay; and our colleagues at the Marine Institute for "making things happen" for the CMI Initiative: Kevin Clarke, Cathy Dutton, Trevor Pike, Craig Parsons, Brian Feltham, Scott Bruce, and Mike Quinton.

Further reading

Marine Weather Stations
http://weather.gc.ca/marine
Small Craft Harbours
www.dfo-mpo.gc.ca/sch-ppb
SmartAtlantic
www.smartatlantic.ca
Coastal Marine Informatics
http://iprox.mi.min.ca/cmi

Jim Wyse (right) is a retired Memorial University Professor of Information Systems. His teaching areas included systems analysis and design, electronic commerce, relational database management, mobile applications development, and information systems management. His research output has appeared in various forms: academic journal articles, conference proceedings, scholarly book chapters, patents, and software copyrights. Dr. Wyse completed his PhD at the University of Western Ontario's Ivey School of Business. Although he claims to be retired and reports spending much of his time sailing throughout coastal Newfoundland and Labrador, it is strongly suspected that he continues his research, software development, systems construction, and consulting activities as Chief Technology/Scientific Officer with Maridia Research Associates.

Mark Wareham (left) is a naval architect with the Fisheries and Marine Institute of Memorial University. He holds technical diplomas in Naval Architecture as well as Marine Engineering Systems Design and has a degree from Memorial University in Ocean and Naval Architectural Engineering. For the last 13 years he has been teaching at the Marine Institute, acting as Chair of the Marine Engineering Systems Design program for 10 of those years. Mr. Wareham is an avid sailor and is actively involved in the promotion of boating within Atlantic Canada. He is a past director with the Wooden Boat Museum of Newfoundland as well as the Newfoundland and Labrador Sailing Association, and he continues to act as a director with the Atlantic Marine Trades Association. He is co-chair of the Regional Recreational Boating Advisory Council.