A Risk-based Methodology of Assessing the Adequacy of Charting Products in the Arctic Region: Identifying the Survey Priorities of the Future

Presented to the NOAA Hydrographic Services Review Panel
RDML Gerd Glang, NOAA
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Adapted from Paper for US Hydro 2015, National Harbor MD By LCDR Michael O. Gonsalves, NOAA
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Background

• In 2014, the Arctic Regional Hydrographic Commission responded to a request by the Arctic Council’s Protection of the Arctic Marine Environment (PAME) working group on the status of Arctic Charting.
Area of Study

Acknowledgements:
• Canadian Hydrographic Service
• Norwegian Mapping Authority
• Danish Geodata Agency
Isn’t the Arctic already charted?

- Chart coverage doesn’t equal data quality...
ARHC’s methodology to assess charting adequacy:

1. Assess confidence of the present hydrographic holdings (Age of data, Type of coverage, etc.).
2. Divide ocean into general depth bands (shallow, mid-depth, deep) factoring in seafloor complexity.
   Ex: across a broad flat shelf, 30m could be considered “deep”; whereas, in areas with the potential for sharp, sudden rises in the seafloor, 50m could be considered “shallow”)
3. Intersect confidence (#1) with depth bands (#2) to develop potential areas of concern.
   Ex: Higher conf. hydro plus deeper depths = Lower concern
   Ex: Lower conf. hydro plus shallower depths = Higher concern
4. Assess historic traffic patterns as they relate to the areas of concern (#3).
5. Generate maps and statistics which can guide decision-making processes.
   Ex: Hydrographic organizations can determine survey priorities
   Ex: Coast Guards can determine where to stage equipment for or spill response events.
Methodology

1. Determine Confidence of Hydrographic Holdings.

- Measuring Equipment Used
- Age of Data
- Surveying Technique
- Other

Assessing Arctic Survey Adequacy Methodology Flow Chart

2. Define Depth Bands based on Seafloor Complexity.

- Simple: 0-20m 20-50m > 50m
- Complex: 0-100m 100-200m > 200m

- Depth + Seafloor Complexity

3. Intersect Areas of Confidence with Depth Areas to determine Potential Areas of Concern.

- (e.g. Higher Confidence and/or Deeper Depths)

- Lowest Concern
- Low Concern
- Med. Concern
- High Concern
- Highest Concern

- (e.g. Lower Confidence and/or Shallower Depths)


- Satellite-Observed Vessel Traffic Patterns

- Higher Consequence Vessels:
  - Tankers
  - Cargo and Tugs
  - Passenger Vessels

- Output:
  - Frequency of Vessels transiting within Areas of Higher/Lower Concern...
  - ... thus quantifying whether region is adequately charted.

5. Compute Area Geometry of Potential Areas of Concern and Linear Distance Traversed by Vessel Traffic within each Area type.
<table>
<thead>
<tr>
<th>Data Type</th>
<th>Relative Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confidence of Hydrographic Data</td>
<td>Low: Newer; 'full' bottom coverage</td>
</tr>
<tr>
<td></td>
<td>High: Older; partial bottom coverage</td>
</tr>
<tr>
<td>Water Depth</td>
<td>Low: Deep</td>
</tr>
<tr>
<td></td>
<td>High: Shallow</td>
</tr>
<tr>
<td>Density of Traffic</td>
<td>Low: Light traffic</td>
</tr>
<tr>
<td></td>
<td>High: Heavy traffic</td>
</tr>
</tbody>
</table>
## Phase 1: Confidence of Hydrographic Data...

<table>
<thead>
<tr>
<th>Country</th>
<th>Data Quality Metric</th>
<th>Confidence Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States and Canada</td>
<td>CATZOC</td>
<td><strong>High</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Category A:</strong> Controlled, systematic survey with high position and depth accuracy. Data acquired using multibeam echosounder, channel, or mechanical sweep system.</td>
</tr>
<tr>
<td>Norway and Denmark</td>
<td>Equipment Type</td>
<td><strong>Medium</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Category B:</strong> Controlled, systematic survey achieving similar depth accuracy to Category A surveys, but with less position accuracy. Data acquired using modern survey echosounder.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Low</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Category C:</strong> Opportunistic survey achieving low depth and position accuracy. Equipment not specified.</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Unassessed</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Pre-acoustic survey equipment or equipment not specified.</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Unassessed</strong></td>
</tr>
</tbody>
</table>
Step 1: Confidence of Hydrographic Data...

1. Determine Confidence of Hydrographic Holdings.

- Measuring Equipment Used
  - High Confidence
- Age of Data
  - Med. Confidence
- Surveying Technique
  - Low Confidence
- Other
  - Unassessed

Legend:
- High confidence
- Med. confidence
- Low confidence
- Unassessed
Step 2: Depth and Seafloor Complexity...
Step 2: Depth and Seafloor Complexity...

- **Shallow**: 0-20m
- **Mid-depth**: 20-50m, > 50m
- **Deep**: > 200m

2. Define Depth Bands based on Seafloor Complexity.

- **Simple**: 0-20m, 20-50m, > 50m
- **Complex**: 0-100m, 100-200m, > 200m

Legend:
- Shallow (0-20m)
- Mid-depth (20-50m)
- Deep (>50m)
Step 3: Intersection of Confidence & Depth...

3. Intersect Areas of Confidence with Depth Areas to determine Potential Areas of Concern.

(e.g. Higher Confidence and/or Deeper Depths)

- Lowest Concern
- Low Concern
- Med. Concern
- High Concern
- Highest Concern

(e.g. Lower Confidence and/or Shallower Depths)
Step 3: Intersection of Confidence & Depth...
Step 3: Intersection of Confidence & Depth...

- Already, we have a reasonable hierarchy for a determination of survey priorities.
- One could reasonably argue that all three of the bays marked with the ‘*’ are worthy of consideration for updated bathymetry.
- ... still vast swaths of ocean; so, where are folks navigating?
Step 4: Incorporation of vessel traffic...


- Notice there are three shallow bays with an Unassessed confidence (marked with an *)....
- While all three were previously identified as potential areas of concern, only the center one experiences heavy traffic (thus, it could be increased in survey priority over the others).
Step 5: Generate metrics...

5. Compute Area Geometry of Potential Areas of Concern and Linear Distance Traversed by Vessel Traffic within each Area type.

Higher Consequence Vessels:
- Tankers
- Cargo and Tugs
- Passenger Vessels

Output:
- Frequency of Vessels transiting within Areas of Higher/Lower Concern...
- … thus quantifying whether region is adequately charted.
Step 5: Arctic-wide metrics...

Two factors at play:

- Hydrographic offices are surveying where vessels are going.
- Vessels are navigating where there is high confidence bathymetry.
How does the United States compare?
United States metrics...

### AREA

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>High (sq. km)</th>
<th>%Total</th>
<th>Medium (sq. km)</th>
<th>%Total</th>
<th>Low (sq. km)</th>
<th>%Total</th>
<th>Unassessed (sq. km)</th>
<th>%Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow</td>
<td>7,151</td>
<td>0.4%</td>
<td>46,340</td>
<td>2.4%</td>
<td>61,288</td>
<td>3.2%</td>
<td>101,443</td>
<td>5.3%</td>
</tr>
<tr>
<td>Mid-Depth</td>
<td>2,280</td>
<td>0.1%</td>
<td>48,647</td>
<td>2.6%</td>
<td>150,830</td>
<td>7.9%</td>
<td>252,610</td>
<td>13.2%</td>
</tr>
<tr>
<td>Deep</td>
<td>3,613</td>
<td>0.2%</td>
<td>6,111</td>
<td>0.4%</td>
<td>368,836</td>
<td>19.3%</td>
<td>838,347</td>
<td>44.0%</td>
</tr>
<tr>
<td>Total</td>
<td>13,044</td>
<td>0.7%</td>
<td>121,098</td>
<td>6.3%</td>
<td>580,954</td>
<td>30.5%</td>
<td>1,192,400</td>
<td>62.5%</td>
</tr>
</tbody>
</table>

### TRAFFIC

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>High (LNM)</th>
<th>%Total</th>
<th>Medium (LNM)</th>
<th>%Total</th>
<th>Low (LNM)</th>
<th>%Total</th>
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<th>%Total</th>
</tr>
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<tr>
<td>Shallow</td>
<td>5,595</td>
<td>0.3%</td>
<td>31,657</td>
<td>1.4%</td>
<td>11,598</td>
<td>0.5%</td>
<td>160,641</td>
<td>7.3%</td>
</tr>
<tr>
<td>Mid-Depth</td>
<td>2,034</td>
<td>0.1%</td>
<td>40,244</td>
<td>1.8%</td>
<td>66,028</td>
<td>3.0%</td>
<td>24,854</td>
<td>1.1%</td>
</tr>
<tr>
<td>Deep</td>
<td>320,822</td>
<td>14.5%</td>
<td>21,633</td>
<td>1.0%</td>
<td>1,393,156</td>
<td>62.9%</td>
<td>137,675</td>
<td>6.2%</td>
</tr>
<tr>
<td>Total</td>
<td>328,451</td>
<td>14.8%</td>
<td>93,534</td>
<td>4.2%</td>
<td>1,470,782</td>
<td>66.4%</td>
<td>323,170</td>
<td>14.6%</td>
</tr>
</tbody>
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## United States

### AREA

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## ‘Whole’ Arctic

Two methods for improving the percentage of traffic within these areas of high confidence bathymetry:

- Targeted surveying in heavily transited areas of high concern.
- Development of offshore transit corridors.

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‘High Confidence’ regions proxy for modern survey work...
Targeted surveys...

- Port Clarence & Kotzebue Sound: relatively shallow, low confidence bathy in areas that are heavily transited.
- Point Hope & Cape Prince of Wales: mariners diverting preferred tracks due to low confidence bathymetry.
Transit Corridors...

- Partnering with the U.S. Coast Guard to develop an offshore transit corridor between Aleutians and Bering Strait.
- Increase high confidence bathymetry, encouraging mariners to alter transits into these corridors.
Proposed Trackline Survey Plan to Address the USCG-Proposed PARS Transit Corridor between the Aleutian Islands and Bering Strait

Red lines acquired by USCG
Blue lines acquired by NOAA
Total corridor width - 7500 meters
Proposed line spacing - 500 meters

Transit Corridors...
Of course, some caution must be exhibited when drawing conclusions from AIS data...

- When the supposition is “retreating sea ice will lead to increased marine traffic”, past navigation trends (while informative) are of limited value.
Speaking towards Arctic charting adequacy...

• On the one hand, only a small percentage of the Arctic (20%), can be characterized as being of lower concern...

• ... however, a disproportionately large percentage of the vessel traffic (77%) occurs within this region.

Identifying survey priorities in the Arctic...

• This study suggests a targeted risk-based approach, elevating the priority of shallow regions, with low quality bathymetric data that are heavily transited.

• In addition, the U.S. will pursue the development of offshore survey corridors in broad regions of high concern.