RUSALCA 2009
Postcruise Workshop

Taxonomy and Zoogeography of Arctic Marine Fishes and Detection of Change

Montenegro, 10 October 2010

Presentation by Kitty and Tony Mecklenburg
Minor revisions, 17 Feb 2011

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Nota Bene:

This presentation is a descendant of previous works and collaborations, as well as containing much new data which could not have been collected without help and cooperation, and we are grateful to all who contributed. Please see the full Acknowledgments in:


The latter paper was in press at the time of the Montenegro workshop. Published online on 1 December 2010, publication in print form should not be far behind. Many of the slides in this workshop presentation illustrate results or discussions in the paper.

Photographs used in this presentation are by CW Mecklenburg unless otherwise credited, and maps by TA Mecklenburg.
RUSALCA 2009 Fish Taxonomy & Zoogeography Studies

USA:

Catherine W. Mecklenburg
Research Associate, California Academy of Sciences;
Point Stephens Research, Auke Bay, Alaska

T. Anthony Mecklenburg
Point Stephens Research, Auke Bay, Alaska

Russia:

Natalia V. Chernova
Zoological Institute, Russian Academy of Sciences,
St. Petersburg
Outline of Presentation:

1) Fishes caught by RUSALCA 2009 bottom trawls
2) Arctic Marine Fish Museum Specimens evaluation & database
3) DNA sequencing (“barcoding”) of Arctic fishes
4) Taxonomic solutions, distribution patterns, & change
5) Fishes caught by RUSALCA in the Chukchi Borderland, 2009
Cruise objectives:

1) Trawl for bottom fishes at the same stations sampled in 2004, as well as additional stations if conditions permitted.

2) Document the catch by preserving examples of each species caught and archiving them in museums’ permanent fish collections.

3) Obtain tissue samples for DNA sequencing.

4) Collect specimens for taxonomic research.

5) Photograph live and fresh specimens.
Otter trawl stations, RUSALCA 2004 and 2009
RUSALCA 2009:

Otter Trawl

26 stations, including most of the same stations as in 2004, plus 8 new sites in the East Siberian Sea, 2 on the outer continental shelf, and 3 on the upper slope and Chukchi Cap.

Caught 46 species vs. 34 in 2004.

11,578 individual fishes, vs. 1,838 in 2004.

In 2009 the study area was larger, more stations were sampled, net was bigger and had a smaller mesh, and more habitats were sampled, including the continental slope.
Most abundant species

Boreogadus saida
Arctic Cod

Gymnocranathus tricuspis
Arctic Staghorn Sculpin

Lumpenus fabricii
Slender Eelblenny

Myoxocephalus scorpius
Shorthorn Sculpin

Hippoglossoides robustus
Bering Flounder

Lycodes polaris
Polar Eelpout

Anisarchus medius
Stout Eelblenny
New species for RUSALCA

Aspidophoroides monopterygius
Alligatorfish

Eumesogrammus praecisus
Fourline Snakeblenny

Limanda sakhalinensis
Sakhalin Sole

Leptoclinus maculatus
Daubed Shanny

Blepsias bilobus
Sailfin Sculpin

Lycodes turneri
Estuarine Eelpout

First records for East Siberian Sea

**Lycodes raridens**
Marbled Eelpout

2 stations in Long Strait (LS1, LS3)

**Leptoclinus maculatus**
Daubed Shanny

1 station NW of Wrangel Island and 1 in Long Strait (LS1)

**Hippoglossoides robustus**
Bering Flounder

1 station in Long Strait (LS1) and 1 on outer shelf W of Wrangel Island (SS5)

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
All arctic marine fish species

45 families, 242 species (all fishing gears, including surface trawls) (Mecklenburg et al. In press).

RUSALCA 2009 species

14 families, 49 species (otter & beam trawls)
Voucher specimens and specimens for research were deposited in 3 museums:

108 = California Academy of Sciences (CAS)
103 = University of Alaska Museum (UAM)
247 = Zoological Institute, Russian Academy of Sciences (ZIN)

458 jars (1-50 specimens each)

Muscle tissue samples from 192 fishes (1 or more of each species) were sent to the University of Guelph, Biodiversity Institute of Ontario, Canada, for DNA sequencing by the Barcode of Life program. Analysis has been completed.

Muscle tissue samples from 100 fishes were given to the UAM tissue bank.
RUSALCA 2009:

Verification of Museum Collections of Arctic Marine Fishes
Arctic Marine Fish Museum Specimens

September 2010

n = 10,285 lots

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
## Largest Western Arctic Marine Fish Collections Evaluated

<table>
<thead>
<tr>
<th>Institution</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auke Bay Marine Laboratory, NOAA, NMFS, Juneau, Alaska</td>
<td></td>
</tr>
<tr>
<td>California Academy of Sciences, San Francisco</td>
<td></td>
</tr>
<tr>
<td>Canadian Museum of Nature, Gatineau, Quebec</td>
<td></td>
</tr>
<tr>
<td>Hokkaido University Museum of Zoology, Hakodate, Japan</td>
<td></td>
</tr>
<tr>
<td>National Museum of Natural History, Washington, D.C.</td>
<td></td>
</tr>
<tr>
<td>University of Alaska, Museum of the North, Fairbanks</td>
<td></td>
</tr>
<tr>
<td>University of British Columbia, Vancouver, Canada</td>
<td></td>
</tr>
<tr>
<td>University of Washington, Seattle</td>
<td></td>
</tr>
<tr>
<td>Zoological Institute, Russian Academy of Sciences, St. Petersburg</td>
<td></td>
</tr>
</tbody>
</table>

*Collection reviewed by Natalia V. Chernova and Boris A. Sheiko, 2006-2007, for ArcOD.

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Major Historical Collections Reviewed from Within the RUSALCA Study Area

Late 19th century American explorers
Arctic Research Lab, Pt. Barrow, in 1940s–1950s
U.S. Bureau of Commercial Fisheries, 1959, E Chukchi Sea
University of Alaska Fairbanks, 1973; E and W Chukchi Sea
NOAA, NMFS, 1976, NE Bering and SE Chukchi Sea
University of Alaska Fairbanks, 1989–1991; NE Chukchi Sea
Hokkaido University Faculty of Fisheries, 1990–1992, E Chukchi Sea
Only one investigation since 1946 (Andriashev 1952), except for RUSALCA 2004 and 2009, has sampled fishes by bottom trawling in Russian as well as American waters of the Chukchi Sea:

University of Alaska Museum, 1973
Otter trawl stations, Aug–Sep 1973, R/V Alpha Helix, James E. Morrow, University of Alaska Museum

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro

C.W. Mecklenburg & T.A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Most Recent Pacific-Arctic Collections Studied

2004, Chukchi Sea, RUSALCA, RV *Professor Khromov*; C.W. Mecklenburg, D.L. Stein, B.A. Sheiko on board

2006, northeastern Bering Sea near Bering Strait, Norton Sound Economic Development Corporation, biennial bottom trawl survey (frozen specimens sent to us for identification and archiving)

2007, eastern Chukchi Sea; NOAA, NMFS, surface trawl; UAF/Norcross-Holladay beam trawl; C.W. Mecklenburg on board conducting RUSALCA-ArcOD barcode study; vessel *Oscar Dyson*

2007 and 2008, eastern Chukchi Sea, Hokkaido University IPY project; UAF/Norcross-Holladay beam trawl; vessel Oshoro Maru (frozen)

2009, Chukchi Sea, Chukchi Borderland, East Siberian Sea; RUSALCA; RV *Professor Khromov*; C.W. Mecklenburg, N.V. Chernova, and Norcross-Holladay teams on board

Other, smaller collections – e.g., frozen fish sent by NOAA, E. Logerwell PI, Beaufort Sea, 2008

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
The 3rd edition, which will include the RUSALCA 2009 voucher specimen records, is planned to be available online at the ArcOD site in spring or early summer 2011. We are updating the nomenclature and making numerous small corrections to the existing database, as well as adding more historical and recent records.
DNA sequencing by the Barcode of Life project uses a standard region of the mitochondrial cytochrome c oxidase 1 gene (CO1). The statistical analysis discriminates among species, and has been proved useful for a wide variety of organisms from insects, fishes, and birds to mammals, and even macroalgae.

Purpose: to help identify species and resolve taxonomic problems. Too often, morphology is not enough.
RUSALCA–ArcOD fish barcode project (Pacific-Arctic):

Muscle tissue samples were collected from fishes caught during cruises and other sampling in 2007–2009

Locations from Chukchi and Beaufort Seas to Aleutian Islands and Gulf of Alaska

Samples were analyzed at University of Guelph, Canada, by Marine Barcode of Life program
691 tissue samples, including 192 from RUSALCA 2009, were submitted. 684 (99%) were successfully sequenced. Sequences were grouped by statistical “neighbor-joining” in clades (groups) representing 106 species.
Both = *Limanda proboscidea* (Longhead Dab)
Sculpin juveniles – What species are they?
Bering Strait and Chukchi Sea

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Microcottus sellaris
Brightbelly Sculpin

Could they be this species?
Although the juveniles look like *M. sellaris*, they are not this species.
Trichocottus brashnikovi
Hairhead Sculpin

109 mm  RUSALCA 2009

Large, rounded, spiny scales behind pectoral fin

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Trichocottus brashnikovi
Hairhead Sculpin

164 mm TL, NE Bering Sea, 2006

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Trichocottus brashnikovi
Hairhead Sculpin

C.W. Mecklenburg & T.A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Outline of Presentation:

1) Fishes caught by RUSALCA 2009
2) Arctic Marine Fish Museum Specimens evaluation & database
3) DNA sequencing ("barcoding") Arctic fishes
4) Taxonomic solutions, distribution patterns, & change
5) Fishes caught in the Chukchi Borderland, 2009

Results from the 3 lines of investigation insofar as they contribute to topic number 4 have been reviewed and synthesized in a recent paper (Mecklenburg, Møller & Steinke 2010), which we illustrate with more examples in the rest of this presentation than could be accommodated in the paper.
Biodiversity of Arctic Marine Fishes: Taxonomy and Zoogeography

(Marine Biodiversity, 2010)

• Catherine W. Mecklenburg, Research Associate, California Academy of Sciences, San Francisco; Private Consultant, Point Stephens Research, Auke Bay, Alaska

• Peter R. Møller, Head of Vertebrate Zoology and Curator of Fishes, Natural History Museum of Denmark, University of Copenhagen

• Dirk Steinke, Lead Scientist, Barcoding of Marine Life, Biodiversity Institute of Ontario, University of Guelph, Ontario, Canada
C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Samples from NW Atlantic barcoding projects were added to our Pacific-Arctic samples: Baffin Bay and Davis Strait, and Hudson Bay

Increased number of sequences for “pan-Arctic” analysis to 880 from 684

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Saddled Eelpout  
*Lycodes mucosus*

Leister Sculpin  
*Enophrys lucasi*

Antlered Sculpin  
*Enophrys diceraus*

Estuarine Eelpout  
*Lycodes turneri*

Sturgeon Poacher  
*Podothecus accipenserinus*

Veteran Poacher  
*Podothecus veternus*

**Similar in appearance but genetically different**

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Some species “complexes” may not be so complex

Gymnelus species
Eelpouts

Liparis species
Snailfishes

Myoxocephalus scorpius
Shorthorn Sculpin

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Myoxocephalus scorpius
Shorthorn Sculpin

Barcodes from the Baltic Sea to the Bering Sea are identical.

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Gymnelus species

Only two species are in this photo.
CO1 sequences indicate each is only one species, not a complex of species as recently proposed. We (Mecklenburg, Møller, & Steinke 2010) use the original species names and the earlier descriptions and classification (Anderson 1982).

The small divergence between the 2 clades indicates these are probably young species.
Gymnelus viridis
Fish Doctor

Male
174 mm

Female
172 mm

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Gymnelus hemifasciatus
Halfbarred Pout

159 mm
72 mm

Male
128 mm

Female
101 mm

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Liparis bathyarcticus
Arctic Seasnail

Liparis tunicatus
Kelp Snailfish

Liparis fabricii
Gelatinous Seasnail

Liparis gibbus
Variegated Snailfish
Liparis tunicatus
Kelp Snailfish
= All one species
Liparis fabricii
Gelatinous Seasnail

94 mm, RUSALCA 2004

130 mm, RUSALCA 2009

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Very close in appearance, but they are genetically different.

*C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro*
For some species, barcoding confirmed the identity of Pacific and Atlantic populations that evidently have no intervening populations. Previously, in such situations, the two populations were assumed to be different species and given different names.

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Aspidophoroides monopterygius
Alligatorfish

Amphiboreal: species distributed in Pacific and Atlantic but not in between

C.W. Mecklenburg & T. A. Mecklenburg, October 2010. Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Icelus sp.

Male

Female

Icelus spatula

Male

Female

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
What species are new to the Arctic?
**Bathyraja parmifera**

**Alaska Skate**

Kivalina — First record of occurrence in the Chukchi Sea

Skate center of distribution has moved north about 90 km since 1982 (Mueter & Litzow 2008).

Biomass and abundance have increased nearly fourfold since 1975 (Hoff 2006).

Trawl data from J. W. Orr, NOAA, AFSC
Hypsagonus quadricornis

Fourhorn Poacher

Green dot in Chukchi Sea is from Oshoro Maru cruise in 2007

Gap in distribution in eastern Bering Sea is a problem.

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Hypsagonus quadricornis
Fourhorn Poacher

Preferred substrate = gravel
Poor swimmer. Walks, using stiff, finger-like pectoral, pelvic, and anal fin rays and up-and-down tail motions for propulsion (Jensen 2007)

**Hypsagonus quadricornis**
Fourhorn Poacher

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Lamna ditropis
Salmon Shark

2007: Caught at Bering Strait. Adult male. This is the first adequately documented catch north of the southern Bering Sea. Previously, range to Bering Strait was doubted by some authors.

A well-known pelagic species caught by surface trawl.
Zaprora silenus
Prowfish

Found in Chukchi Sea for first time in 2007, by surface trawl. However, surface trawling has been rare in the Chukchi. Our bottom trawls would not have picked it up.

Adults are benthopelagic, live deep, near the bottom; juveniles stay near the surface.

Northern Bering and Chukchi are not deep enough for the adults. If the juveniles are new to the Arctic, will they cross the shelf to settle in the deep slope waters of the Arctic, or die?
Trichocottus brashnikovi
Hairhead Sculpin

Population in Seas of Japan and Okhotsk but nothing in Bering and Chukchi until 1973. Do the new finds in Bering and Chukchi indicate expansion into the Arctic? Or have they been there all along but misidentified? (See slides 26–31.)
Artediellus atlanticus
Atlantic Hookear Sculpin

C.W. Mecklenburg & T. A. Mecklenburg, October 2010, Taxonomy and zoogeography of arctic marine fishes and detection of change, RUSALCA 2009 Postcruise Workshop, Montenegro
Anarhichas denticaulatus
Northern Wolffish

First records from Pacific-Arctic

Most common in NW Atlantic
This part of the RUSALCA 2009 workshop fish presentation will be provided on the RUSALCA website at a later date. Analysis of the Chukchi Borderland collection is nearing completion and manuscripts are in progress.