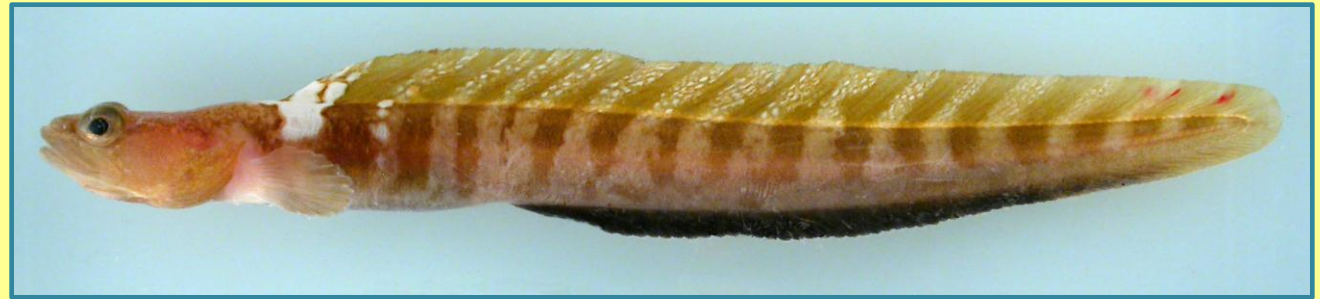


**RUSALCA 2012**

**Precruise  
Workshop**

**Miami, Florida  
11 March 2012**



**What we have learned about  
change in the distribution of  
fishes from the RUSALCA  
mission**

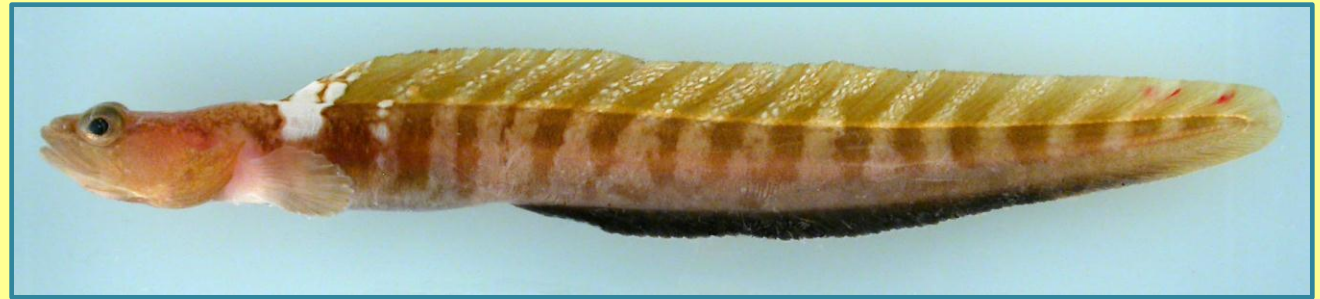


**Presentation by  
C.W. & T.A. Mecklenburg**

**RUSALCA 2012**

**Precruise  
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**Miami, Florida  
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**What we have learned about  
change in the distribution of  
fishes from the RUSALCA**

**mission**



**Presentation by  
C.W. & T.A. Mecklenburg**

# RUSALCA Fish Diversity Assessments

## U.S.:

### **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,  
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### **Boris A. Sheiko**

Zoological Institute, Russian Academy of Sciences,  
St. Petersburg

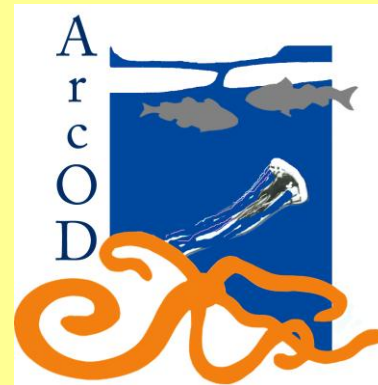
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\*Onboard in 2012. Assisted by Arve Lynghammar, Ph.D. Student, University of Tromsø, Norway.

# Biodiversity of Arctic Marine Fishes: Taxonomy and Zoogeography

(*Marine Biodiversity*, Published)

- **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





Arctic Region  
(green)

## Biodiversity of arctic marine fishes: taxonomy and zoogeography

Catherine W. Mecklenburg · Peter Rask Møller · Dirk Steinke

Received: 3 June 2010 / Revised: 23 September 2010 / Accepted: 1 November 2010 / Published online: 1 December 2010  
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**Abstract** Taxonomic and distributional information on each fish species found in arctic marine waters is reviewed, and a list of families and species with commentary on distributional records is presented. The list incorporates results from examination of museum collections of arctic marine fishes dating back to the 1830s. It also incorporates results from DNA barcoding, used to complement morphological characters in evaluating problematic taxa and to assist in identification of specimens collected in recent expeditions. Barcoding results are depicted in a neighbor-joining tree of 880 *COI* (cytochrome *c* oxidase I gene) sequences distributed among 165 species from the arctic region and adjacent waters, and discussed in the family reviews. Using our definition of the arctic region, we count 242 species with documented presence, if 12 species that likely are synonyms are excluded. The 242 species are distributed among 45 families.

This article belongs to the special issue "Arctic Ocean Diversity Synthesis"

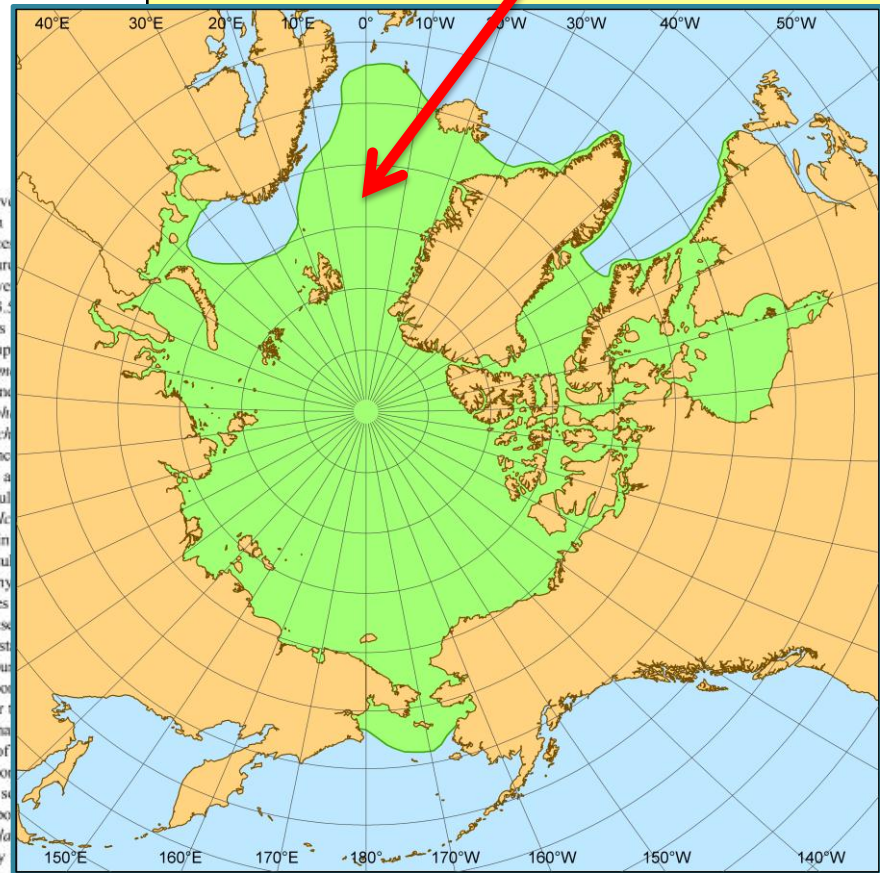
**Electronic supplementary material** The online version of this article (doi:10.1007/s12526-010-0070-z) contains supplementary material, which is available to authorized users

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Six families in Cottoidei with 72 species and five Zoarcoidei with 55 species account for more than (52.5%) the species. This study produced *COI* sequence 106 of the 242 species. Sequence variability in the bar region permits discrimination of all species. The average sequence variation within species was 0.3% (range 0–3.5) while the average genetic distance between congeners 4.7% (range 3.7–13.3%). The *COI* sequences support taxonomic separation of some species, such as *Osmo dentex* and *O. mordax* and *Liparis bathyarticus* and *gibbus*; and synonymy of others, like *Myoxocephalus verrucosus* in *M. scorpius* and *Gymnelus knipowitschi* *G. hemifasciatus*. They sometimes revealed the presence of additional species that were not entirely expected, such as an unidentified species of *Ammodytes* in the western Gulf of Alaska, most likely *A. personatus*; and an unidentified *Leptocottus* species of the *L. spatula* complex with populations in western Gulf of Alaska and the northern Bering and Chukchi Seas which could be a new species or a species in synonymy. Reviewing distribution, we found that for 24 species patterns assigned by authors understated historical presence in the arctic region, and for 12 species they overstated presence. For instance, *Hippoglossoides robustus* is considered as an arctic–boreal species rather than predominantly boreal and *Arctiellus uncinatus* as predominantly arctic rather than predominantly boreal. Species with arctic, predominantly arctic, or arctic–boreal distributions composed 41% of 242 species in the region, and predominantly boreal, boreal, and widely distributed species composed 59%. For some continental shelf species, such as the primarily amphiboreal *Eumesogrammus praecisus* and *Leptoclinius maculatus*, distributions appear to reflect changes, including recent Arctic seas and reestablishment of continuous ranges, that zoogeographers believe have been going on since the end of land bridge and glacial times.

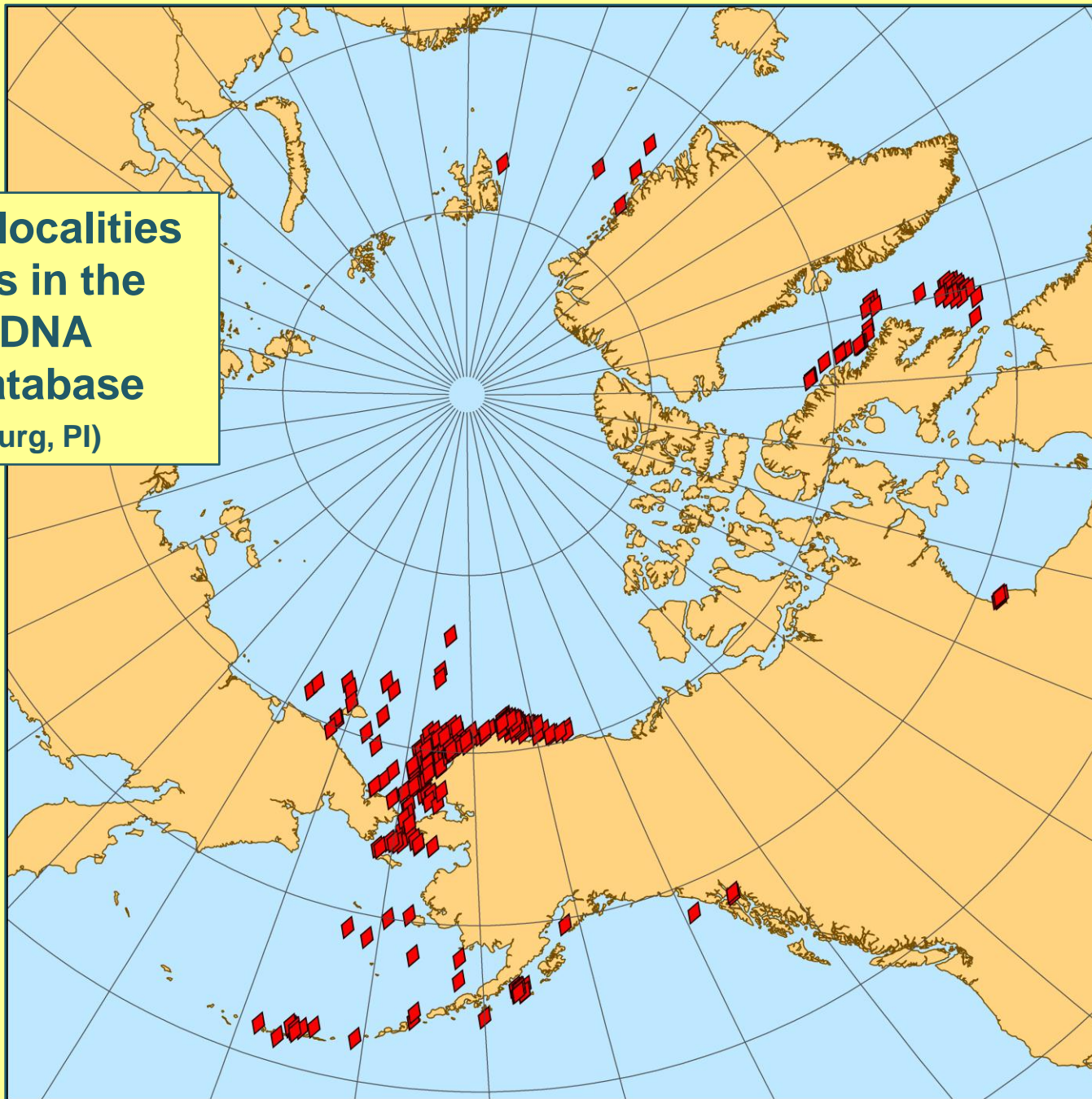


**Collection localities  
for samples in the  
Arctic fish DNA  
barcode database**

(C.W. Mecklenburg, PI)

**1,214 tissue  
samples**

**188 species**





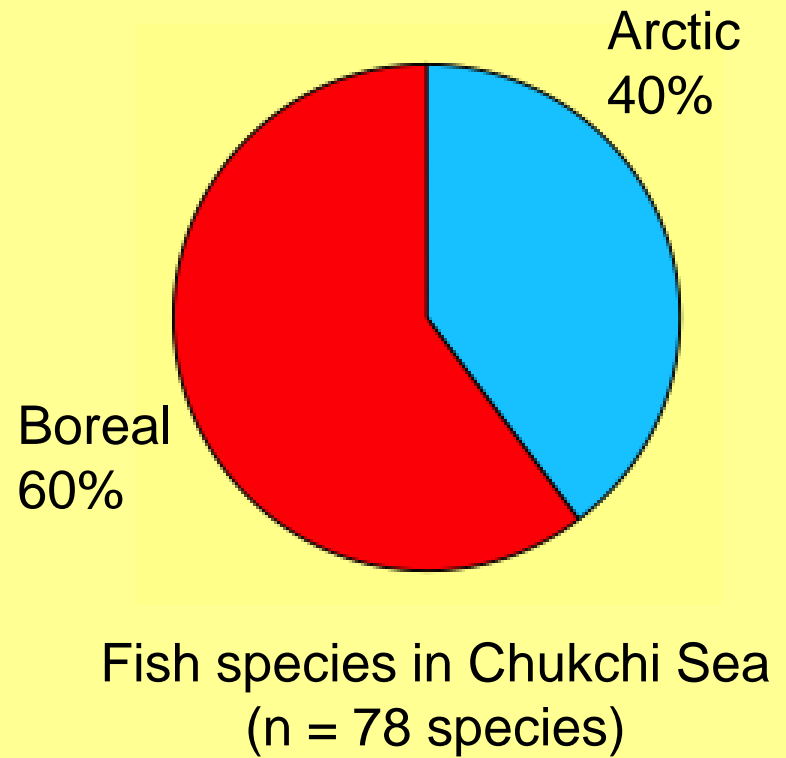
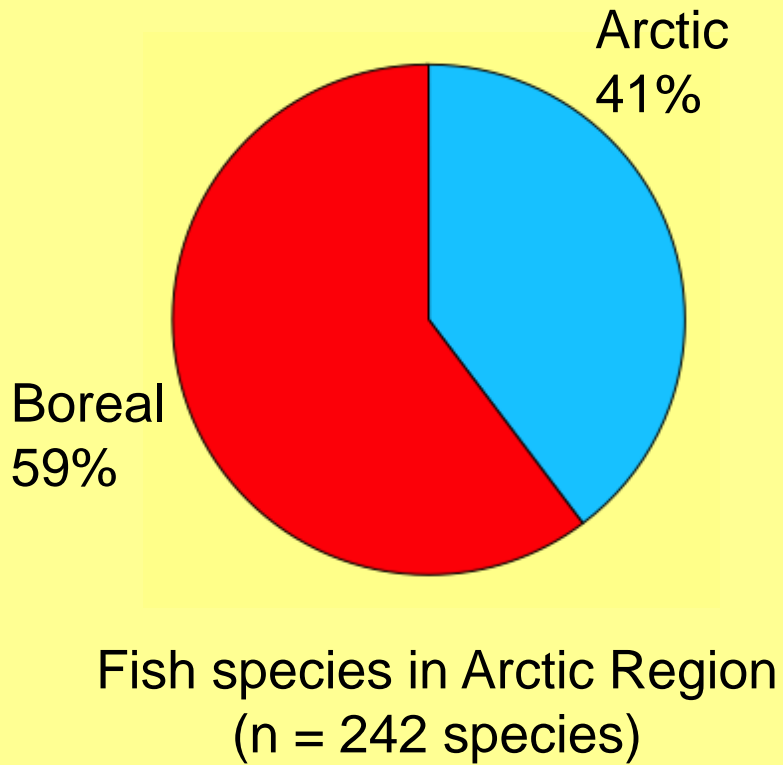
## Synonyms, supported by new data:

- Arctogadus borisovi* Drjagin, 1932 = *Arctogadus glacialis* (Peters, 1872)
- Aspidophoroides bartoni* Gilbert, 1896 = *Aspidophoroides monopterygius* (Bloch, 1786)
- Careproctus dubius* Zugmayer, 1911 = *Careproctus reinhardti* (Krøyer, 1862)
- Cottus groenlandicus* Cuvier, 1829 = *Myoxocephalus scorpius* (Linnaeus, 1758)
- Eumicrotremus eggvinii* Koefoed, 1956 = *Eumicrotremus spinosus* (Fabricius, 1776)
- Gadus callarias marisalbi* Derjugin, 1920 = *Gadus macrocephalus* Tilesius, 1810
- Gadus ogac* Richardson, 1836 = *Gadus macrocephalus* Tilesius, 1810
- Gymnelus barsukovi* Chernova, 1999 = *Gymnelus viridis* (Fabricius, 1780)
- Gymnelus bilabrus* Andriashev, 1937 = *Gymnelus viridis* (Fabricius, 1780)
- Gymnelus knipowitschi* Chernova, 1999 = *Gymnelus hemifasciatus* Andriashev, 1937
- Gymnelus platycephalus* Chernova, 1999 = *Gymnelus hemifasciatus* Andriashev, 1937
- Liparis liparis bathyarcticus* Parr, 1931 = *Liparis bathyarcticus* Parr, 1931
- Lycodes vahli gracilis* Sars, 1867 = *Lycodes gracilis* Sars, 1867
- Lycodes vahli vahli* Reinhardt, 1831 = *Lycodes vahli* Reinhardt, 1831
- Lycodonus ophidium* (Jensen, 1902) = *Lycodonus flagellicauda* (Jensen, 1902)
- Myoxocephalus scorpius groenlandicus* (Cuvier, 1829) = *Myoxocephalus scorpius* (Linnaeus, 1758)
- Myoxocephalus verrucosus* Bean, 1881 = *Myoxocephalus scorpius* (Linnaeus, 1758)
- Myxine limosa* Girard, 1859 = *Myxine glutinosa* Linnaeus, 1758
- Melletes papilio* Bean, 1880 = *Hemilepidotus papilio* (Bean, 1880)
- Theragra chalcogramma* (Pallas, 1814) = *Gadus chalcogrammus* Pallas, 1814
- Theragra finnmarchica* Koefoed, 1956 = *Gadus chalcogrammus* Pallas, 1814
- Trigloopsis quadricornis* (Linnaeus, 1758) = *Myoxocephalus quadricornis* (Linnaeus, 1758)
- Ulcina olrikii* (Lütken, 1877) = *Aspidophoroides olrikii* Lütken, 1877

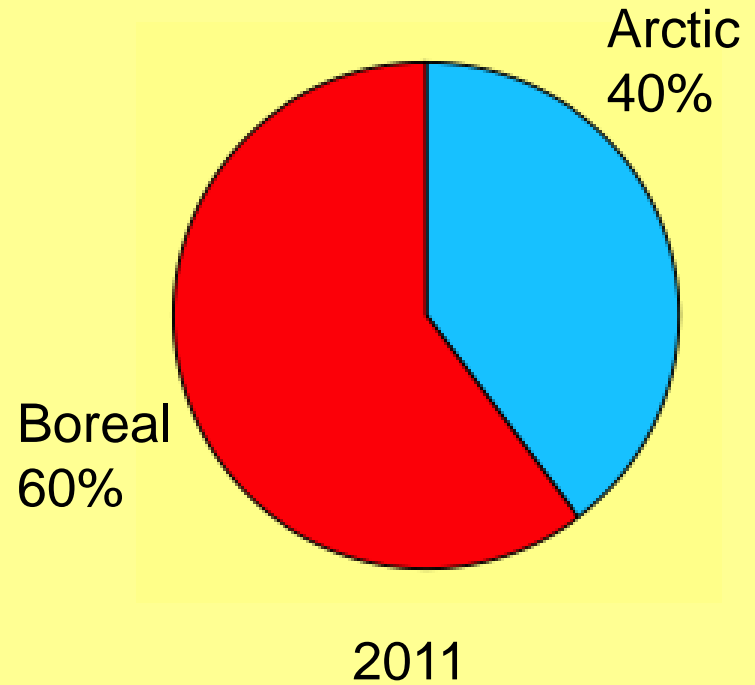
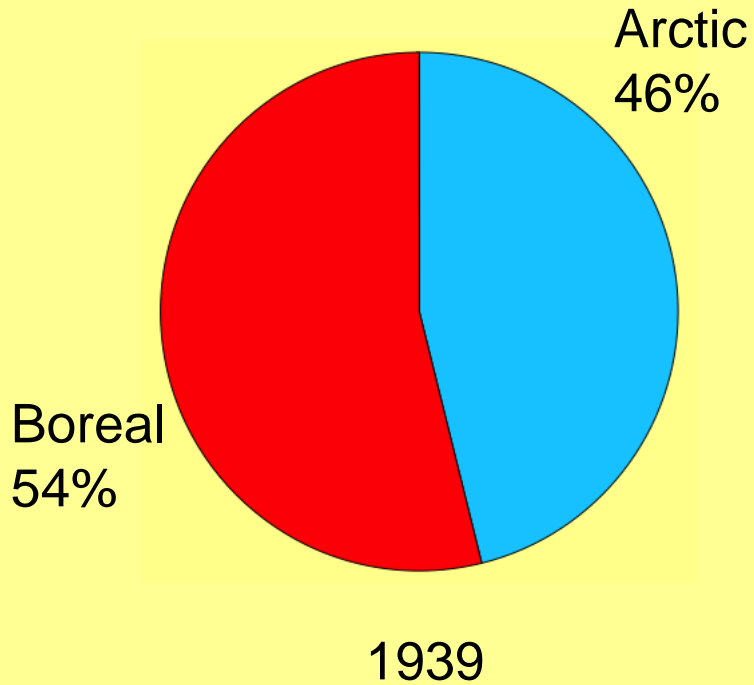
## Relationships needing further study:

- Cottunculus konstantinovi* Myagkov, 1991 = *Cottunculus microps* Collett, 1875?  
*Cottunculus sadko* Essipov, 1937 = *Cottunculus microps* Collett, 1875?  
*Gymnelus andersoni* Chernova, 1998 = *Gymnelus retrodorsalis* Le Danois, 1913?  
*Gymnelus esipovi* Chernova, 1999 = *Gymnelus retrodorsalis* Le Danois, 1913?  
*Gymnelus obscurus* Chernova, 2000 = *Gymnelus viridis* (Fabricius, 1780)?  
*Gymnelus taeniatus* Chernova, 2005 = *Gymnelus retrodorsalis* Le Danois, 1913?  
*Liparis bristolensis* (Burke, 1912) = *Liparis tunicatus* Reinhardt, 1836?  
*Liparis marmoratus* Schmidt, 1950 (in part?) = *Liparis tunicatus* Reinhardt, 1836?  
*Lycodes rossi* Malmgren, 1865 = *Lycodes reticulatus* Reinhardt, 1835?

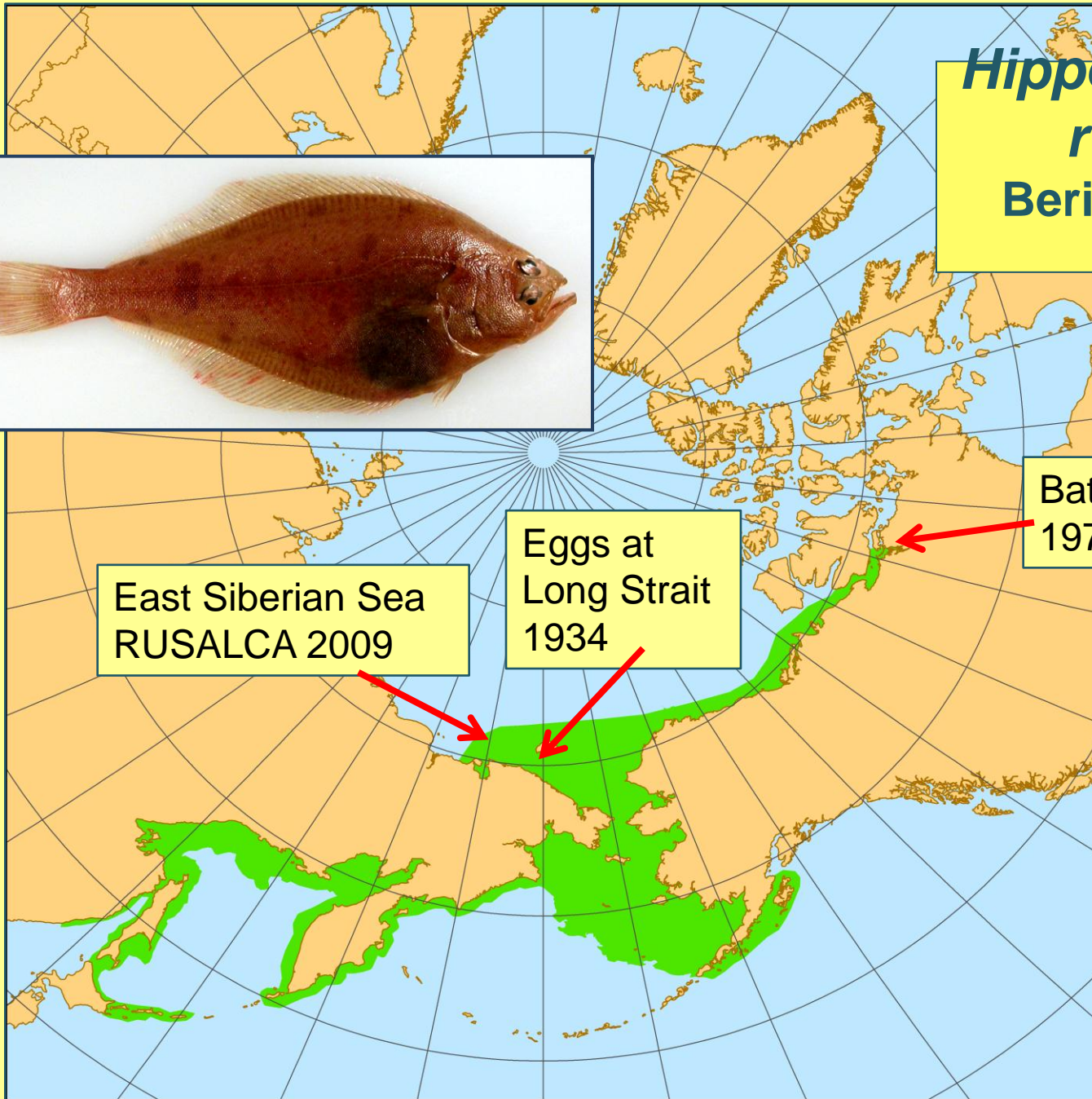




# Marine fish species in the Chukchi Sea



*Hippoglossoides  
robustus*  
Bering Flounder

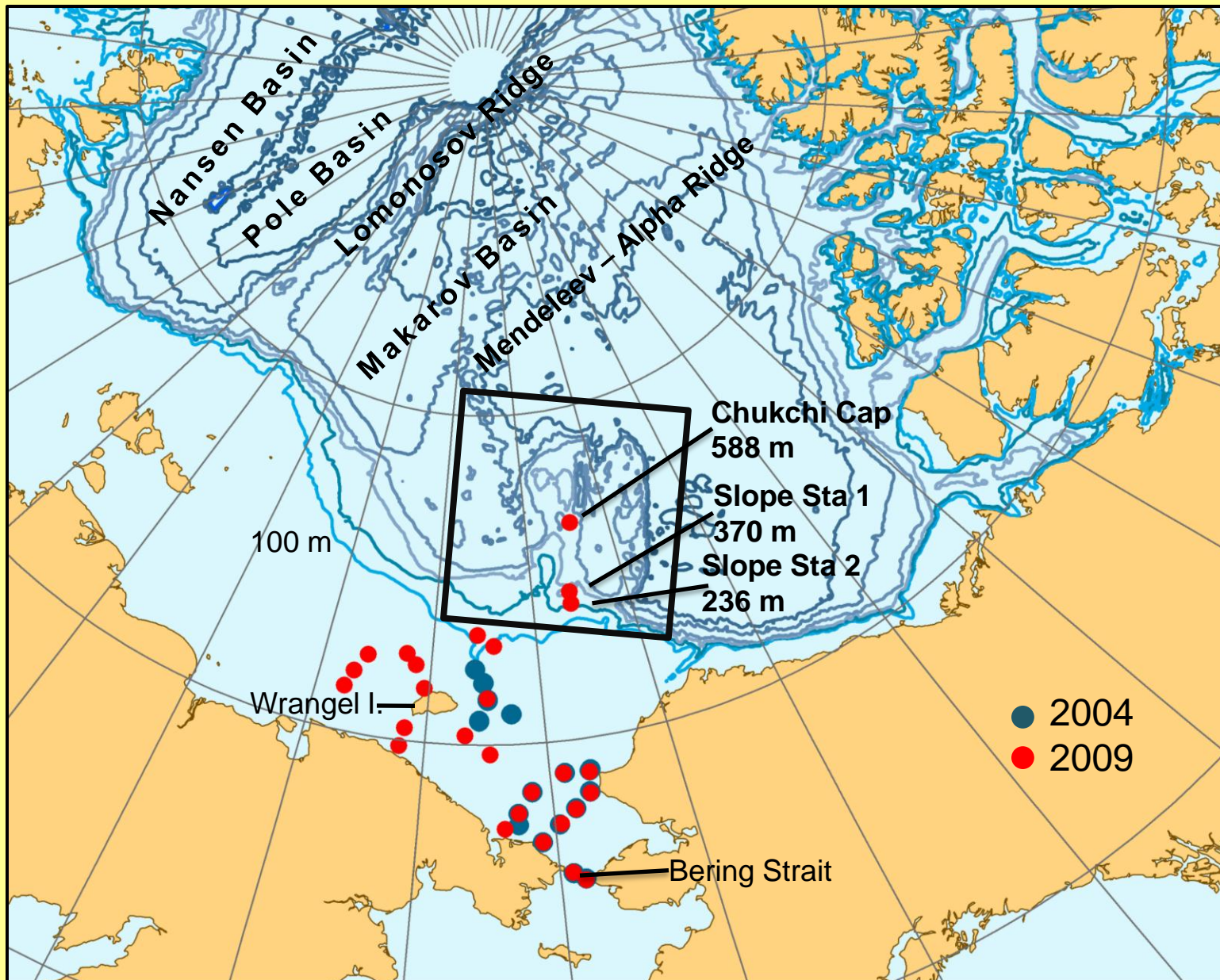


East Siberian Sea  
RUSALCA 2009

Eggs at  
Long Strait  
1934

Bathurst Inlet  
1975

■ Documented  
geographic  
distribution



**RUSALCA Bottom Trawl Stations in Chukchi Borderland**



# Report on TEAM-Fish Workshop I: Arctic Fishes at Stake, Tromsø, Norway, 7 & 8 November 2011

The TUNU-Programme: Euro-Arctic Marine Fishes – diversity and adaptation (TEAM-Fish) addresses biodiversity and ecological issues for conservation and reliable assessments of the marine fishes native to Euro-Arctic waters.

**Workshop Purpose:** The TEAM-Fish Workshop I was the first step towards a collaboration between ongoing and prospective research on Arctic marine fishes in the Euro-Arctic sector and the Far East through the RUSALCA programme (see abstract 1).

**Workshop funding:** Fram Centre

**Workshop convener:** Jørgen S. Christiansen, University of Tromsø, Norway

## Selected abstracts

**1. Catherine W. Mecklenburg**, California Academy of Sciences, USA

### **Russian–American Long-term Census of the Arctic (RUSALCA): Atlantic fishes in the Chukchi Borderland**

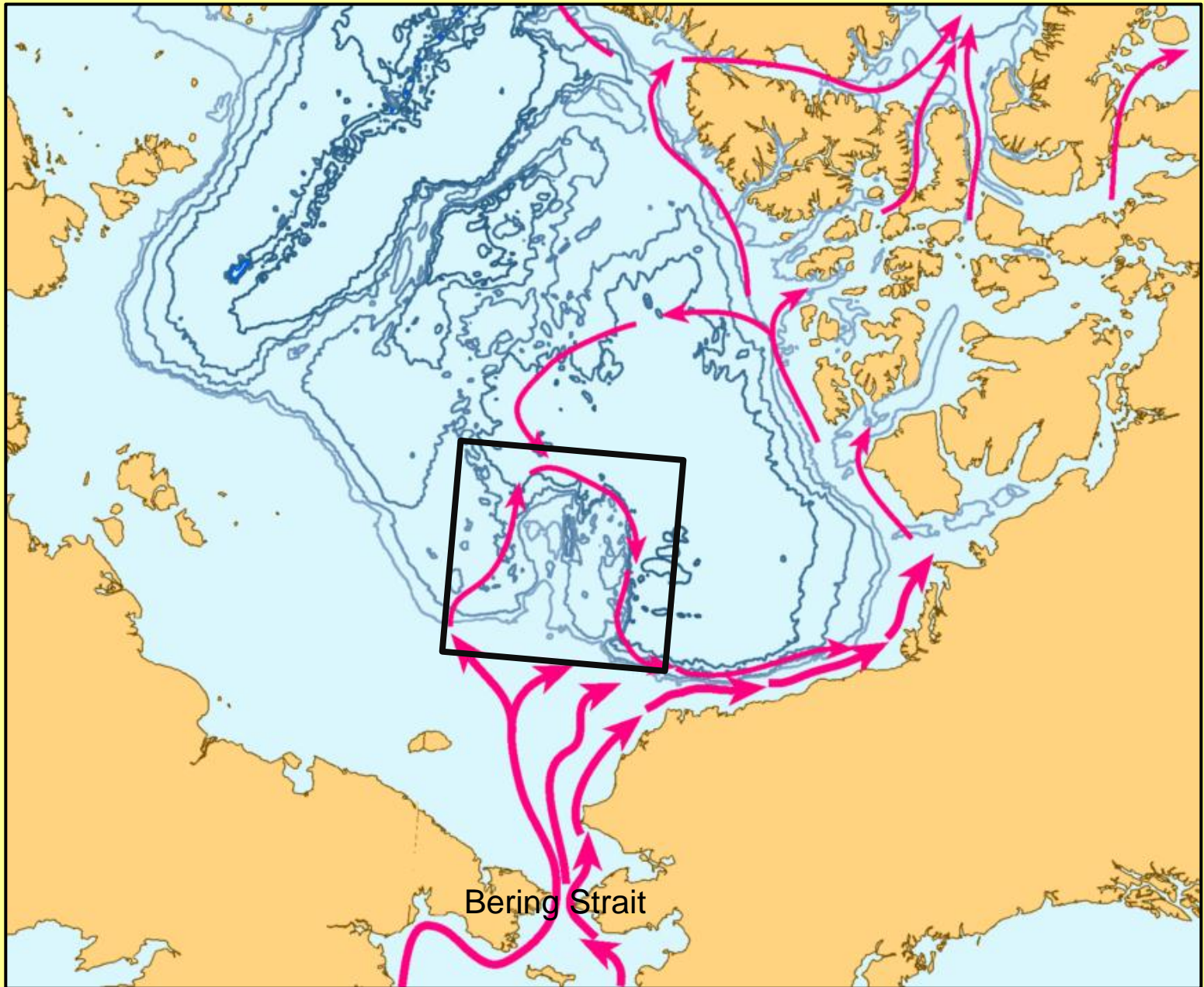
With the retreat of the Arctic sea ice in September 2009, the RUSALCA (Russian–American Long-Term Census of the Arctic) expedition reached north to the Chukchi Borderland, a region of complex seafloor topography that has barely been explored. It had rarely been sampled for fishes, and never by trawling from a ship. One tow of a small bottom trawl net at three sites at depths of 227–588 m was accomplished. We caught 12 species distributed among seven families (Gadidae, Cottidae, Psychrolutidae, Liparidae, Stichaeidae, Zoarcidae, Pleuronectidae) and four orders (Gadiformes, Scorpaeniformes, Perciformes, Pleuronectiformes). These include the first record of *Lycodes adolfi* from the western Arctic, the first record of *Artediellus atlanticus* between the western Laptev Sea and Baffin Bay, and rare records of *Careproctus reinhardtii*, *Cottunculus microps*, *Triglops nybelini*, and *Lycodes seminudus* from the Pacific

# Russian–American Long-term Census of the Arctic (RUSALCA), 2009: Atlantic Fishes in the Chukchi Borderland

TEAM-Fish Workshop  
University of Tromsø  
Tromsø, Norway  
7 November 2011

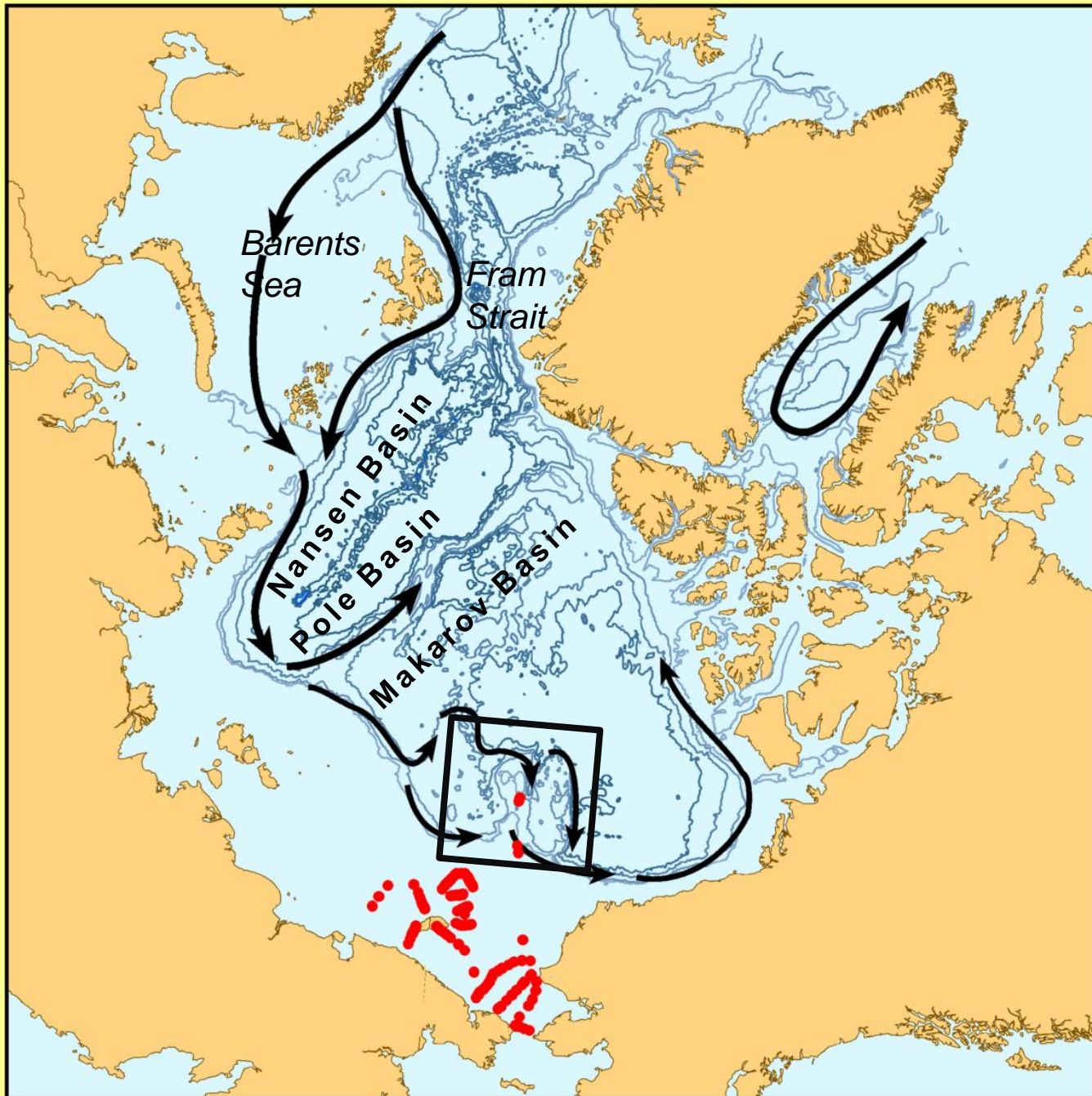


Presentation by C.W. Mecklenburg  
Maps by T.A. Mecklenburg



**Strong outflow of Pacific Water through Bering Strait**





**Atlantic  
Water  
circulation  
in the  
Arctic,  
200–800 m**



# Classification of Species Taken by Otter Bottom Trawl in Chukchi Borderland, 2009

## Gadiformes

Gadidae (cods)

*Arctogadus glacialis*

*Boreogadus saida*

*Gadus chalcogrammus*

## Scorpaeniformes

Cottidae (sculpins)

*Arctodiellus atlanticus*

*Triglops nybelini*

Psychrolutidae (fathead

sculpins)

*Cottunculus microps*

Liparidae (snailfishes)

*Careproctus reinhardti*

*Liparis fabricii*

## Perciformes

Stichaeidae (pricklebacks)

*Leptoclinus maculatus*

Zoarcidae (eelpouts)

*Lycodes adolfi*

*Lycodes seminudus*

## Pleuronectiformes

Pleuronectidae (flounders)

*Reinhardtius hippoglossoides*

Species = 12

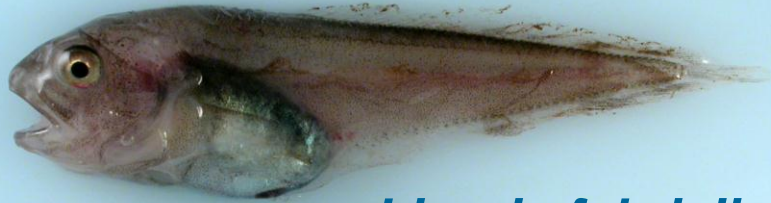
Families = 7

Orders = 4



*Leptoclinus maculatus*

Daubed Shanny



*Liparis fabricii*

Gelatinous Seasnail



*Reinhardtius hippoglossoides*

Greenland Halibut



*Arctogadus glacialis*

Polar Cod



*Boreogadus saida*

Arctic Cod



*Gadus chalcogrammus*

Walleye Pollock

6 species collected in the Chukchi Borderland  
are also found on the continental shelf



*Reinhardtius  
hippoglossoides*

**Greenland Halibut**

Chukchi Borderland:  
1 at 365–370 m

Overall depth range:  
14–2,000 m

Demersal, benthopelagic



arctic–boreal  
Pacific & Atlantic

(amphi-Arctic,  
amphiboreal)



**Gadus**

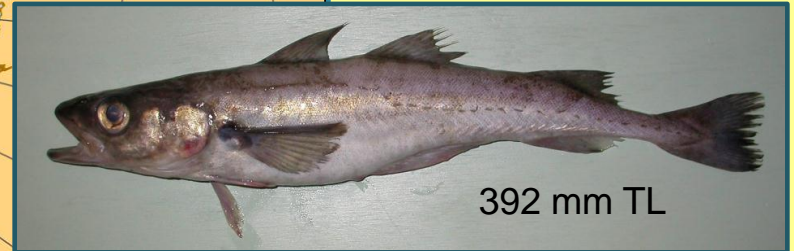
***chalcogrammus***  
**Walleye Pollock**

Norway  
pollock



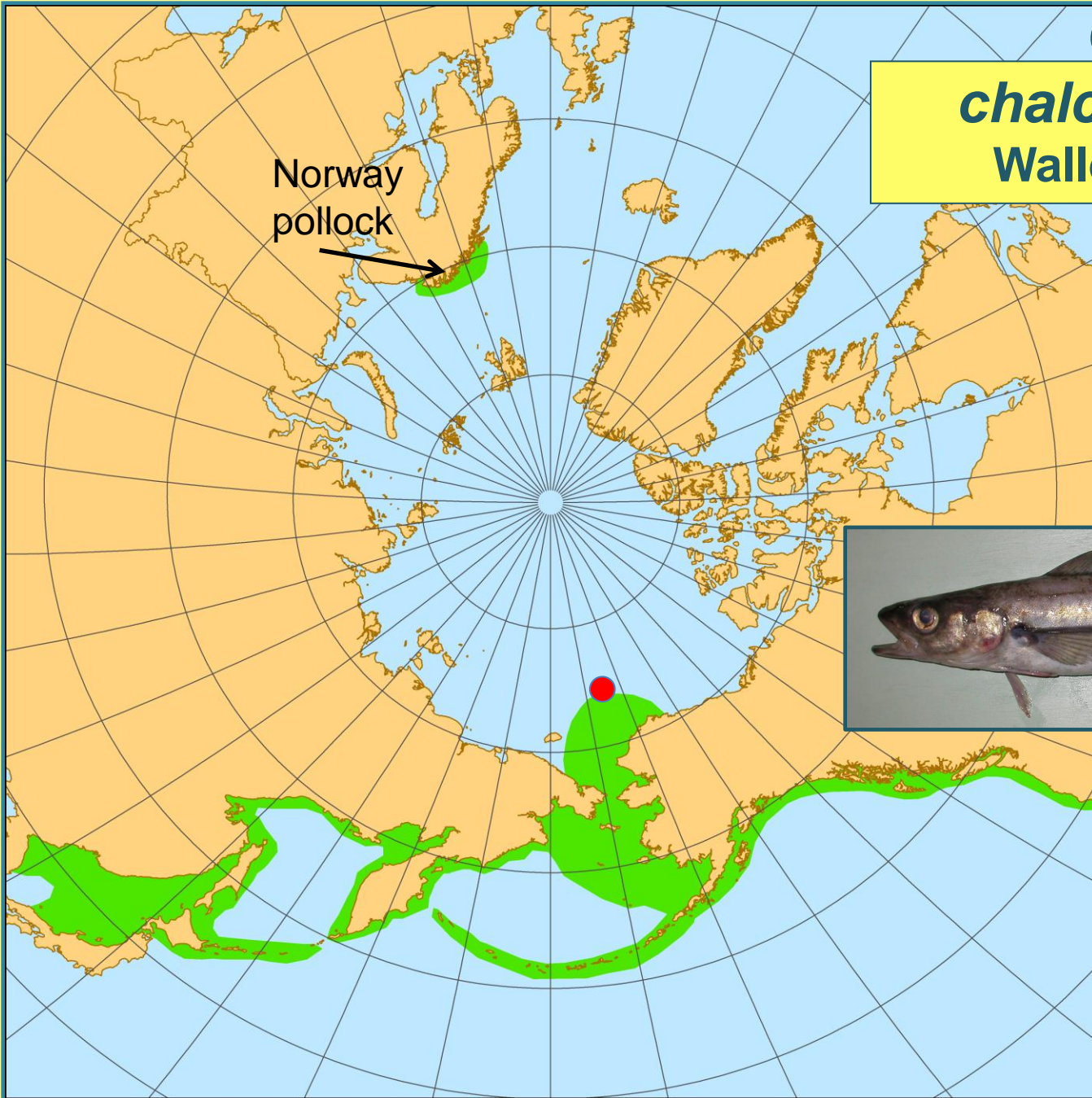
Chukchi Borderland:  
1 at 365–370 m

Overall depth range:  
Surface to 1,200 m  
Demersal & pelagic



predominantly  
boreal Pacific

(amphi-Arctic)







*Artediellus atlanticus*  
Atlantic Hookear Sculpin



*Careproctus reinhardtii*  
Sea Tadpole



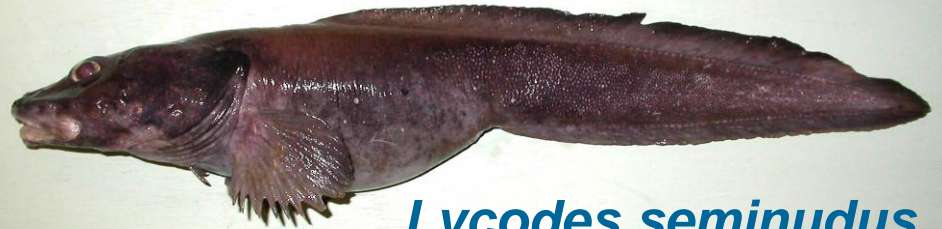
*Lycodes adolfi*  
Adolf's eelpout



*Cottunculus microps*  
Polar Sculpin

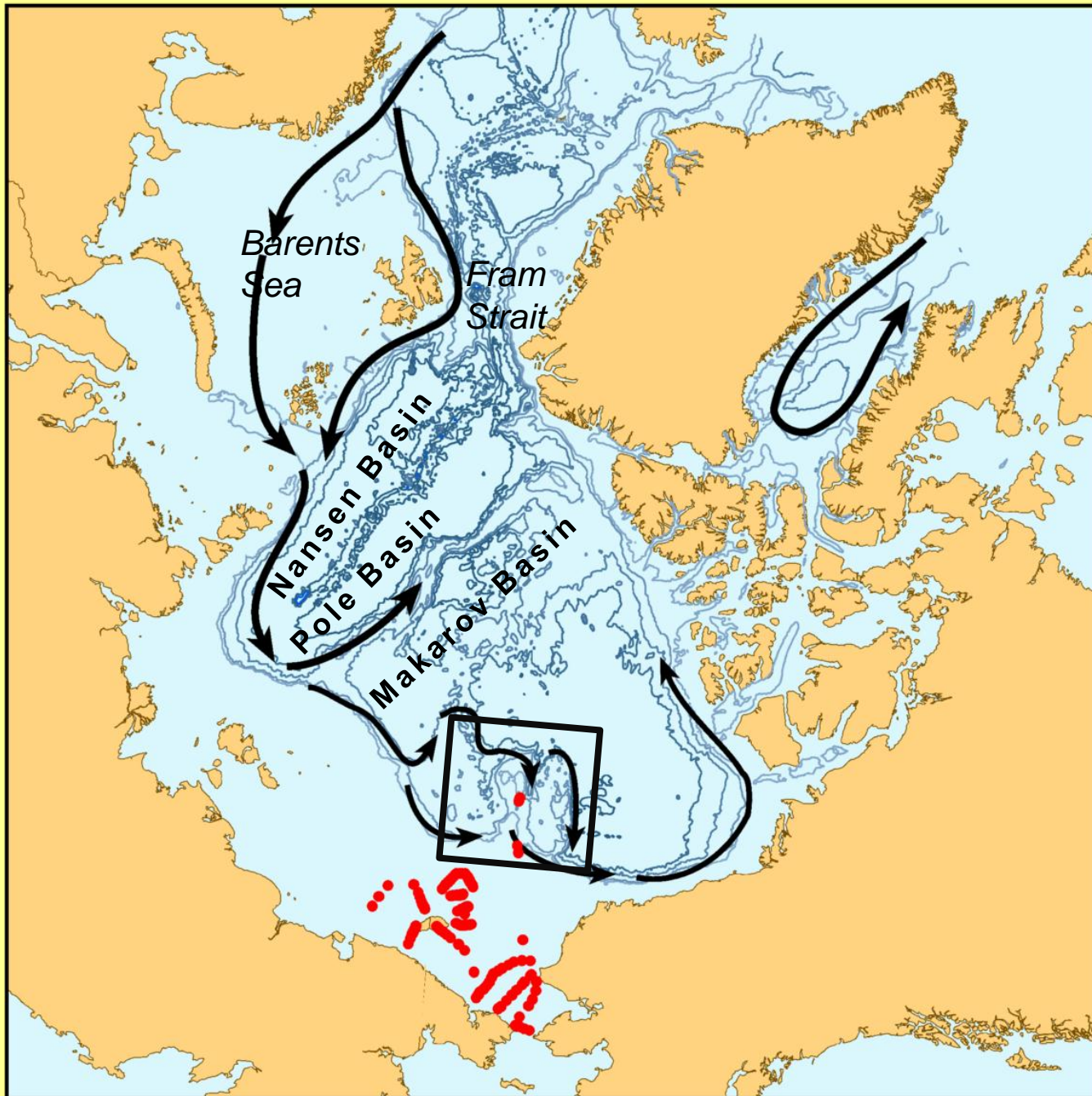


*Triglops nybelini*  
Bigeye Sculpin



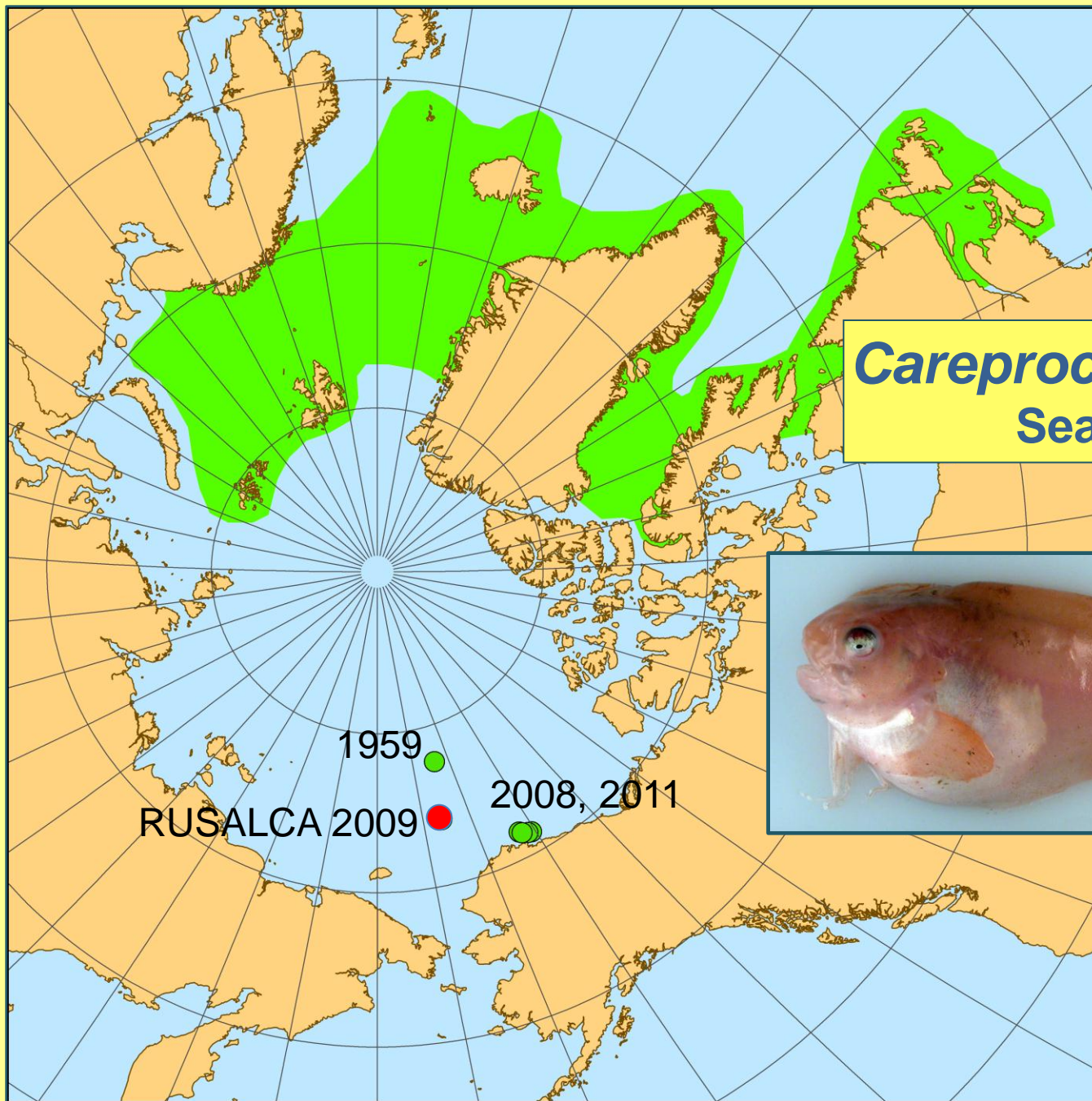
*Lycodes seminudus*  
Longear Eelpout

The other 6 species were found only in the Chukchi Borderland



**Atlantic  
Water  
circulation  
in the  
Arctic,  
200–800 m**





RUSALCA 2009:  
1 at 365–370 m (SL1)

Overall depth range:  
100–1,840 m?  
(Identification problem)  
Benthic

## *Careproctus reinhardtii* Sea Tadpole



170 mm TL

1959 ●  
RUSALCA 2009 ●  
2008, 2011 ●●

Arctic species,  
mainly Atlantic,  
possibly  
circumpolar

# *Cottunculus microps* Polar Sculpin

Chukchi Borderland:  
1 at 365–370 m

Overall depth range:  
159–1,450 m

Benthic



RUSALCA 2009 ● ?

● 1972

arctic–boreal,  
mainly Atlantic,  
possibly  
circumpolar



# *Artediellus atlanticus* Atlantic Hookear Sculpin

Chukchi Borderland:  
5 at 227–236 m  
2 at 365–370 m

Overall known depth range:  
11–1,366 m  
Benthic



142 mm TL

arctic–boreal,  
mainly Atlantic,  
possibly  
circumpolar



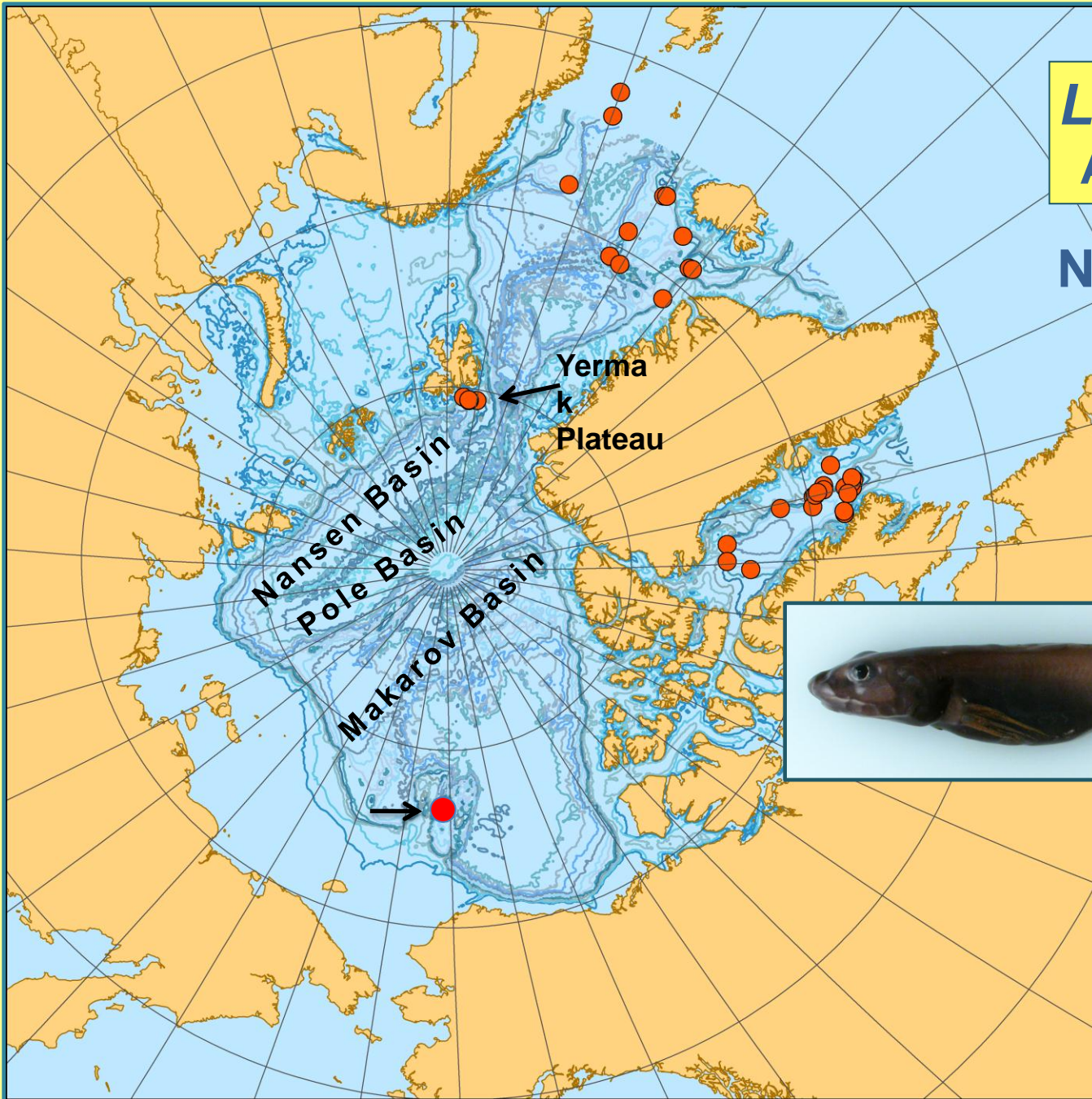


*Lycodes adolfi*  
Adolf's Eelpout

Nielsen & Fosså 19

Chukchi Borderland:  
4 at 580–588 m

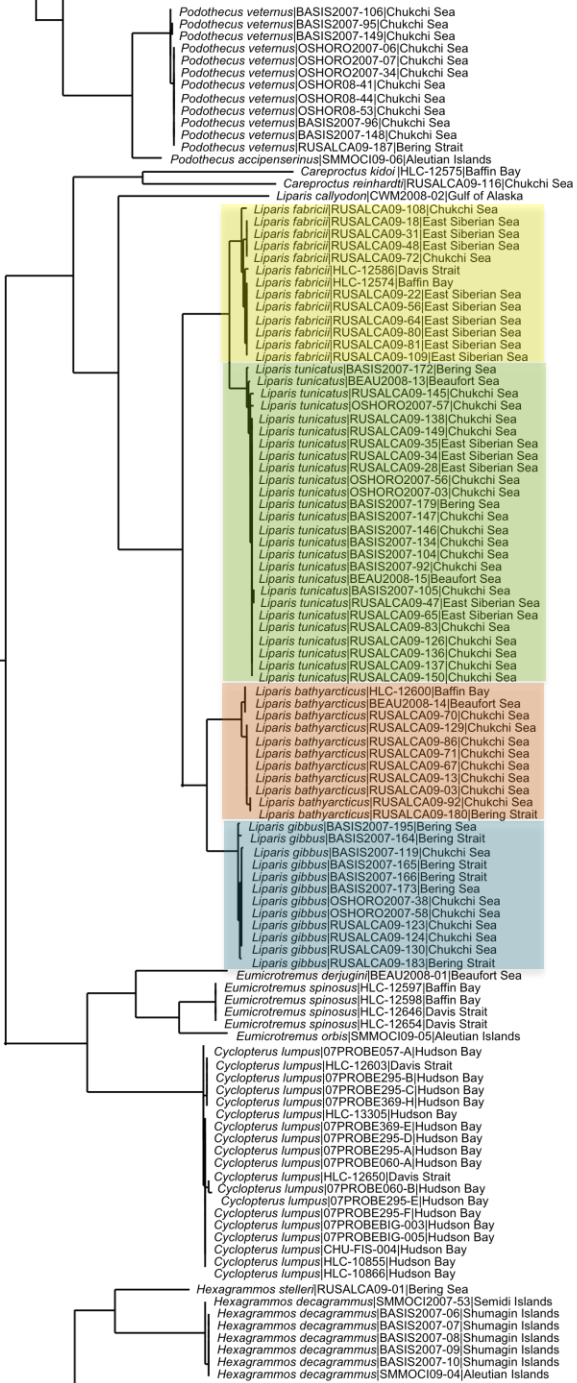
Overall depth range:  
386–1,880 m  
Benthic



arctic, mainly  
Atlantic,  
probably  
circumpolar

# **Fishes of the Arctic Ocean and Adjacent Seas**

**A distributional atlas and  
identification guide to the  
Arctic marine ichthyofauna**



*Liparis fabricii*  
Gelatinous Seasnail

*Liparis tunicatus*  
Kelp Snailfish

*Liparis bathyarcticus*  
Arctic Seasnail

*Liparis gibbus*  
Variegated Snailfish

DNA sequences  
(barcodes)  
indicate 4 distinct  
species of *Liparis*  
are present





***Liparis gibbus***  
**Variegated Snailfish**



***Liparis***  
***bathyarcticus***  
**Arctic Seasnail**

**Very close in appearance, yet they are genetically different.**

# The Most Active Collaborators So Far

## Russia:

Oleg V. Karamushko, Murmansk Marine Biological Institute  
Boris A. Sheiko, Zoological Institute, St. Petersburg

## Norway:

Ingvar Byrkjedal, Bergen Museum  
Jørgen S. Christiansen, University of Tromsø  
Arve Lynghammar, University of Tromsø  
Camilla Ottesen Meyer, University of Tromsø

## Denmark:

Peter R. Møller, Zoological Museum, University of Copenhagen

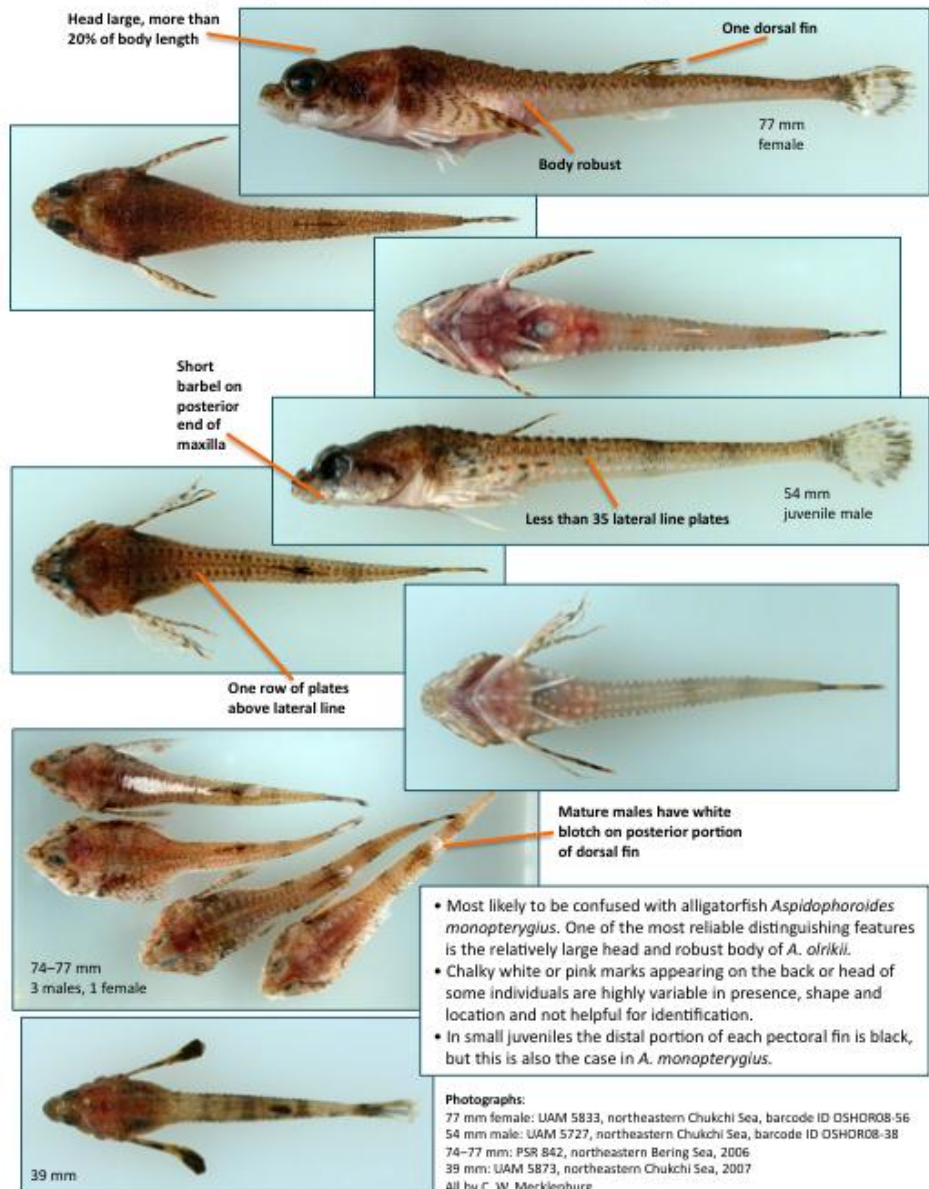
## Canada:

Dirk Steinke, Barcode of Life, University of Guelph  
Danny Kent, Vancouver Aquarium

## U.S.:

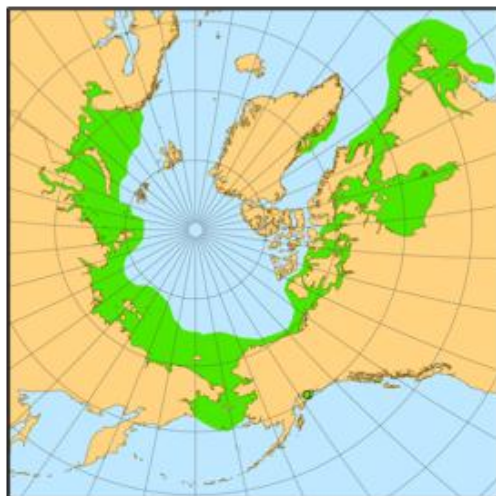
Brenda A. Holladay, University of Alaska Fairbanks  
Milton Love, University of California, Santa Barbara  
T. Anthony Mecklenburg, Point Stephens Research, Alaska

### *Aspidophoroides olrikii* Arctic alligatorfish





## Agonidae — Poachers

*Aspidophoroides olrikii* Lütken, 1877 Arctic alligatorfish

French name: poisson-alligator arctique  
 Norwegian name: arktisk panserulke  
 Russian name: (ledovitomorskaya lisitchka)

**Distribution:** Predominantly Arctic, nearly circumpolar: southern Barents Sea and White Sea eastward to west Greenland, southward to northern Bering Sea and the Newfoundland banks.

**Habitat:** Benthic, found at depths of 7–520 m, usually < 100 m; temperatures mostly below 0°C; salinity 33–35‰; mostly on muddy and muddy-sandy substrate.

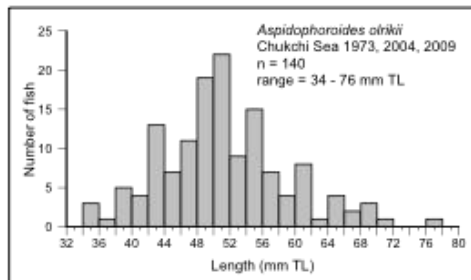
**Identifying features:** Brownish to greenish brown on back and upper sides fading to white below; three darker saddle bands or blotches and dark band around base of caudal fin; dorsal fin blackish; anal and pelvic fins white; caudal fin blackish brown with white area in center and white along margin. Posterior area of dorsal fin chalky white in males. Bands are darker and more distinct in juveniles. Body elongate and robust; mouth terminal; **head broad, large, more than 20% of standard length.**

**One dorsal fin** (the first is absent), with 5–7 rays, opposite anal fin with 5–7 rays. Plates on body and top of head flat, without spines or keels; supralateral row of plates absent, leaving **one row of plates above lateral line**; 40 or fewer plates in lateral line row; single row of plates along midline of breast. Nasal spine (paired) present, nearly indiscernible to well developed. **Short barbel on posterior end of maxilla.** Small juveniles (about 40 mm or less) differ from the adults by having pectoral fins with a narrow blackish band in the middle and broad blackish distal portion, spinelike keels on the plates, a projecting lower jaw, and the anus situated farther posteriorly.

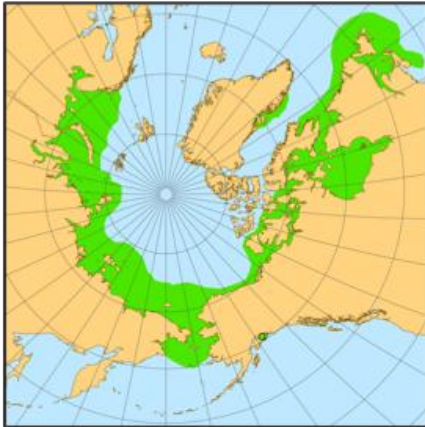
**Life history:** Females spawn 110–250 eggs about 1.7 mm diameter on the seafloor (Andriashev 1986). Up to 260 well developed eggs as well as numerous smaller eggs have been observed present in ovaries (Frost and Lowry 1983). **Adults attain 89 mm total length** (Andriashev 1961). Largest of 140 *A. olrikii* taken in bottom trawls in the Chukchi Sea in 1973, 2004, and 2009 was 76 mm.

**Diet:** Small benthic invertebrates including gammarid amphipods, polychaete and nemertine worms, and ostracods. Eaten by halibuts (*Hippoglossus*) and other bottom fishes.

**Relative abundance in arctic region:** The most abundant poacher in bottom trawl surveys of the Chukchi and Beaufort Seas, where this species has ranked 5–12th in abundance by number of fish caught in research sampling (e.g., Frost and Lowry 1983, Mecklenburg et al. 2007, and unpublished catch records from 1973 and 2009 cruises). Uncommon to rare in northern boreal (subarctic) waters. In the Gulf of St. Lawrence was found at only 3% of the stations (Nozères et al. 2010). In the Bering Sea, rare south of St. Matthew Island, only one or two records (Mecklenburg et al. 2011).



## Agonidae — Poachers

*Aspidophoroides olrikii* Lütken, 1877 Arctic alligatorfish

French name: poisson-alligator arctique  
 Norwegian name: arktisk panserulke  
 Russian name: (ledovitomorskaya lisitchka)

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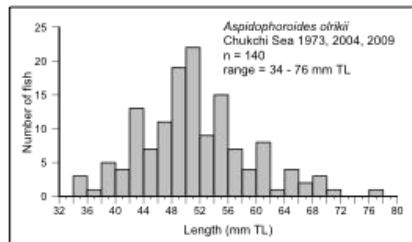
**Identifying features:** Brownish to greenish brown on back and upper sides fading to white below; three darker saddle bands or blotches and dark band around base of caudal fin; dorsal fin blackish; anal and pelvic fins white; caudal fin blackish brown with white area in center and white along margin. Posterior area of dorsal fin chalky white in males. Bands are darker and more distinct in juveniles. Body elongate and robust; mouth terminal; **head broad, large, more than 20% of standard length.**

**One dorsal fin** (the first is absent), with 5–7 rays, opposite anal fin with 5–7 rays. Plates on body and top of head flat, without spines or keels; supralateral row of plates absent, leaving **one row of plates above lateral line**; 40 or fewer plates in lateral line row; single row of plates along midline of breast. Nasal spine (paired) present, nearly indiscernible to well developed. **Short barbel on posterior end of maxilla.** Small juveniles (about 40 mm or less) differ from the adults by having pectoral fins with a narrow blackish band in the middle and broad blackish distal portion, spinellike keels on the plates, a projecting lower jaw, and the anus situated farther posteriorly.

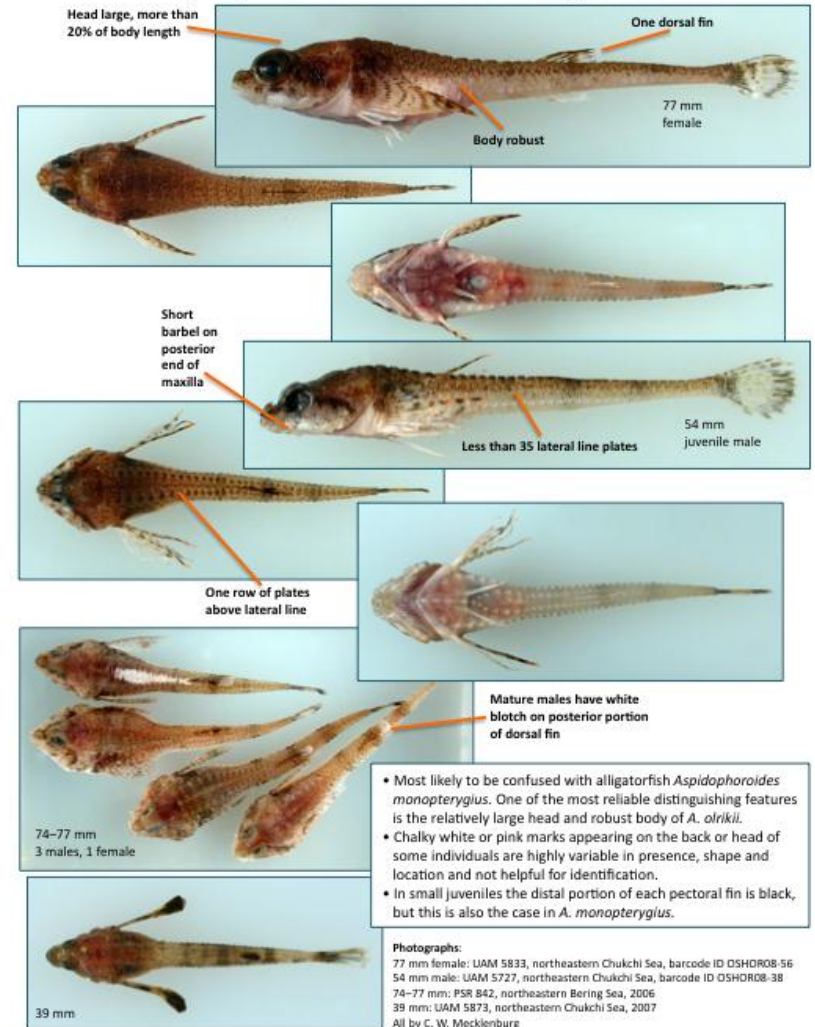
**Life history:** Females spawn 110–250 eggs about 1.7 mm diameter on the seafloor (Andriashev 1986). Up to 260 well developed eggs as well as numerous smaller eggs have been observed present in ovaries (Frost and Lowry 1983). **Adults attain 89 mm total length** (Andriashev 1961). Largest of 140 *A. olrikii* taken in bottom trawls in the Chukchi Sea in 1973, 2004, and 2009 was 76 mm.

**Diet:** Small benthic invertebrates including gammarid amphipods, polychaete and nemertine worms, and ostracods. Eaten by halibuts (*Hippoglossus*) and other bottom fishes.

**Relative abundance in arctic region:** The most abundant poacher in bottom trawl surveys of the Chukchi and Beaufort Seas, where this species has ranked 5–12th in abundance by number of fish caught in research sampling (e.g. Frost and Lowry 1983, Mecklenburg et al. 2007, and unpublished catch records from 1973 and 2009 cruises). Uncommon to rare in northern boreal (subarctic) waters. In the Gulf of St. Lawrence was found at only 3% of the stations (Nozères et al. 2010). In the Bering Sea, rare south of St. Matthew Island, only one or two records (Mecklenburg et al. 2011).



Family: Agonidae — Poachers

*Aspidophoroides olrikii* Arctic alligatorfish

**Taxonomic status:** Not currently identified as problematic. *Aspidophoroides güntheri* Bean, 1885 was described as a separate new species from Alaska but was later shown to be the same as *A. olrikii* (Rendahl 1931). Classified for a time in *Ulcina*, this species was recently returned to *Aspidophoroides* (Mecklenburg et al. 2011).

Collection localities for barcoded specimens from the northern Bering Sea, the East Siberian, Chukchi and Beaufort Seas are given in Appendix X.

**Taxonomic Serial Number:** 692156

**Commercial significance:** Not commercially fished.

**Notes on Distribution:** Not known from the Canadian high Arctic archipelago, northern Baffin Bay, east Greenland to Norwegian Sea and northern Barents Sea (Mecklenburg et al. 2011). In bottom trawl surveys of the Barents Sea during 2004–2009, was found only in the eastern part off Novaya Zemlya (Wienerroither et al. 2011). The presence of a single record [UAM 1171, confirmed by CWM] indicates a disjunct population in Prince William Sound, northern Gulf of Alaska, perhaps a relict of former colder times (Mecklenburg et al. 2011).

**Notes on Habitat:** To 250 m in the Canadian Arctic at Bathurst Inlet, 400 m in the Beaufort Sea off Alaska (Frost and Lowry 1983), 200–300 m in Barents Sea (Andriashev 1986). The extreme depth of 520 m is from the Kara Sea (Andriashev 1986). At temperatures of 2–3°C in the White Sea and western Greenland (Andriashev 1986). At salinities of 23–28‰ in East [?] Siberian and White Seas (Andriashev 1986). At –1.7°C and salinity of 33.32 to 7.9°C and salinity of 31.30 in the Chukchi Sea in 2004 (Mecklenburg et al. 2007); in 2009, \_\_\_\_\_.

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# RUSALCA 2012: Fish Diversity & Otter Trawling

Cruise objectives for 2012 are the same as for 2009, slightly modified:

- 1) Deploy the otter trawl at selected stations sampled in 2009, omitting those that were nonproductive in terms of species diversity, and trawl twice rather than once at some other stations.
- 2) Document the catch by preserving examples of each species caught and archiving them in the PIs' museums' permanent fish collections (CAS, UAM, ZIN).
- 3) Obtain tissue samples for DNA sequencing. Analyses in addition to barcoding will be conducted. All tissue-sampled fishes need to be photographed and archived to provide proper documentation.
- 4) Collect specimens for taxonomic research. Natalia and I need specimens for study of morphological characters, not just for archiving as species identification vouchers.
- 5) Photograph live and fresh specimens to fill remaining gaps in the atlas & guide. There are still a lot of gaps.