Distribution patterns of squid in the upper epipelagic Gulf of Alaska in winter 2019

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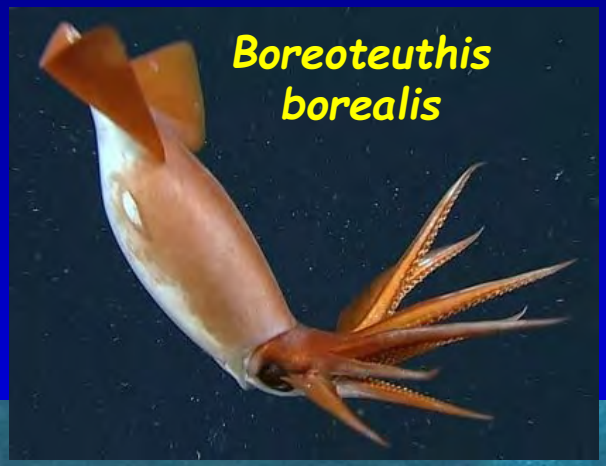
Onychoteuthis
borealijaponica


Gonatus onyx


Boreoteuthis
borealis


Okutania anonycha


Gonatus madokai


Abraliopsis
felis

This is how those critters look when they come from the trawl net

Project Title: Species Identification of Squid

Richard Beamish
Leon Shaul
Oleg Katugin

General Description and Objectives:

Squid are an important component of the diet of salmon in offshore waters of the Gulf of Alaska and Bering Sea and therefore are an integral component of the growth, maturation, and survival of salmon on the high seas.

Maturing epipelagic squid are particularly important in the diet of higher trophic level species (coho, chinook, steelhead), while occupying an important trophic position as intra-guild prey of pink and sockeye salmon. Top-down control of squid by pink salmon has the potential to influence the salmon forage base at different trophic levels as well as growth of other salmon species. The carrying capacity of the offshore Gulf of Alaska for salmon likely varies depending upon specific species and their relationship with squid. Despite their importance, relatively little is known about squid populations on the high seas, including their life cycle, population structure, spawning areas, and movement at different life stages relative to ocean currents.

Genetic samples from squid of various stages will be used as necessary to validate species ID, help confirm the lifespan of a key species found in salmon diets, and begin investigating genetic differentiation within *Okutania anonycha* (also known as *Berryteuthis anonychus*) across the North Pacific and Bering Sea.

Species ID: morphology, molecular genetics (CO1)

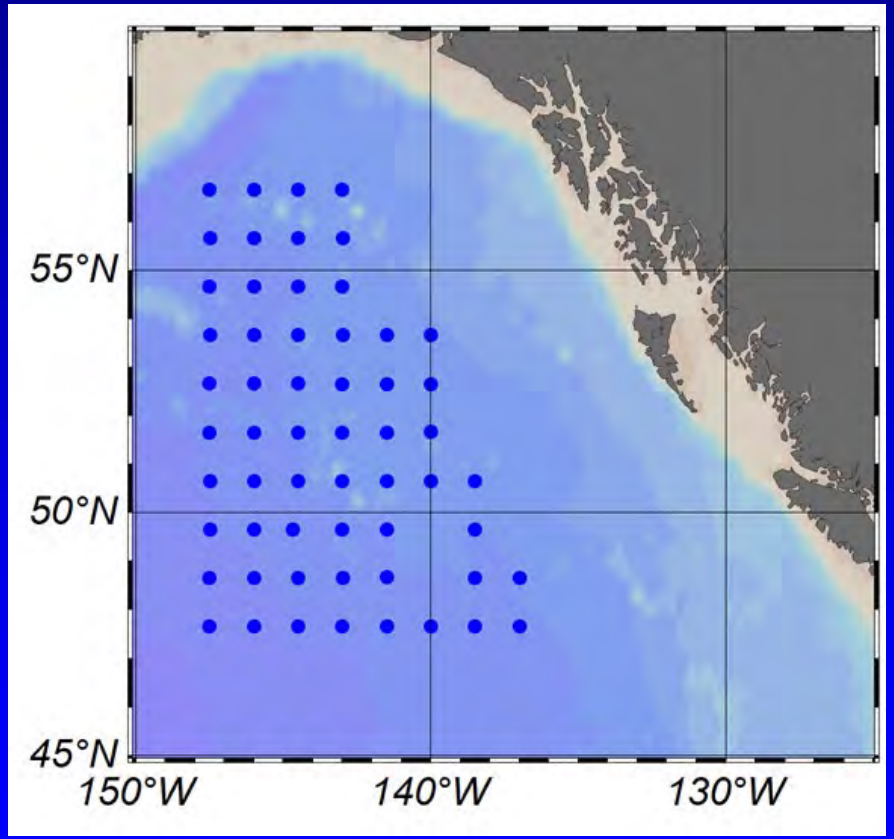
Life Cycle: 1 year vs 2 years in *Okutania anonycha* **???**

Genetic Differentiation and Environmental History: spatial population structure; odd- and even-year lines in *Okutania anonycha* **???**

Collection Protocol: While *O. anonycha* is likely to be the most dominant species encountered, other species will likely be present including these highly abundant species: *Boreoteuthis borealis*, *Gonatus kamtschaticus*, *Berryteuthis magister*, *Gonatus onyx*, and other Gonatid species
(**1. Surface Trawls: 2. Salmon and other fish Diets:**)

Research Objectives

- Analyze distribution patterns of cephalopods in the GoA in the early spring 2019 based on the upper epipelagic trawl catches



Research Objectives

- Take a closer look at the occurrence of highly abundant species in the research area in the upper epipelagic layer, and at species that were expected to occur in large quantities in the GoA
- Use the existing sources of information on distribution of cephalopods in the NPO:

(1) TINRO database on trawl catches collected in expeditions

(2) GBIF (*Global Biodiversity Information Facility—is an international network and research infrastructure with an open access to data about all types of life on Earth.*

gbif.org

Research Objectives

- analyze the occurrence of selected abundant and potentially abundant cephalopod species in the NPO with respect to geophysical and biotic factors, which may predict distribution patterns of those species
- Use the Bio-Oracle (Marine Data Layers for ecological modeling) to produce potential habitat for the selected cephalopod species in MaxEnt

bio-oracle.org

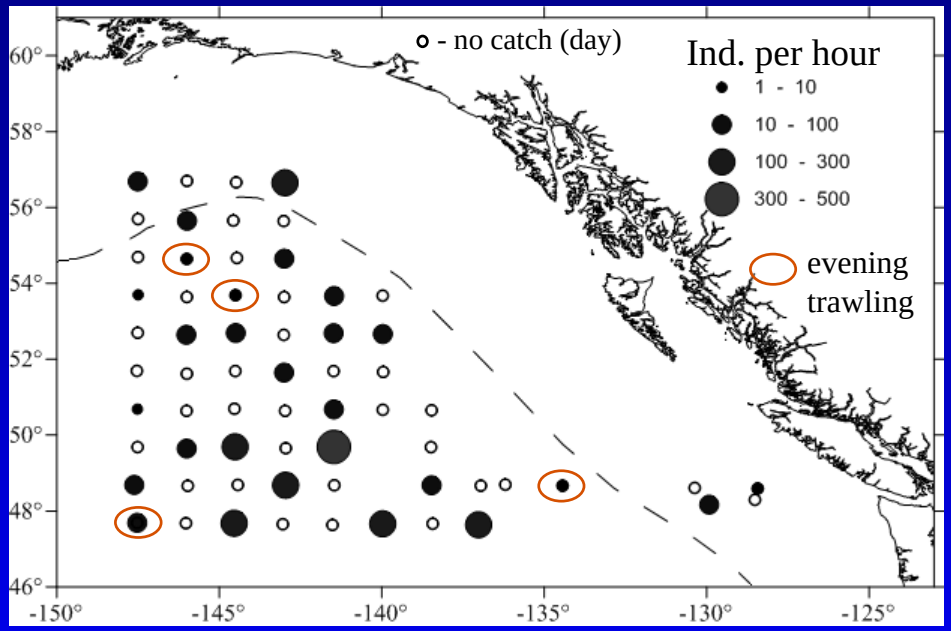
Research Objectives

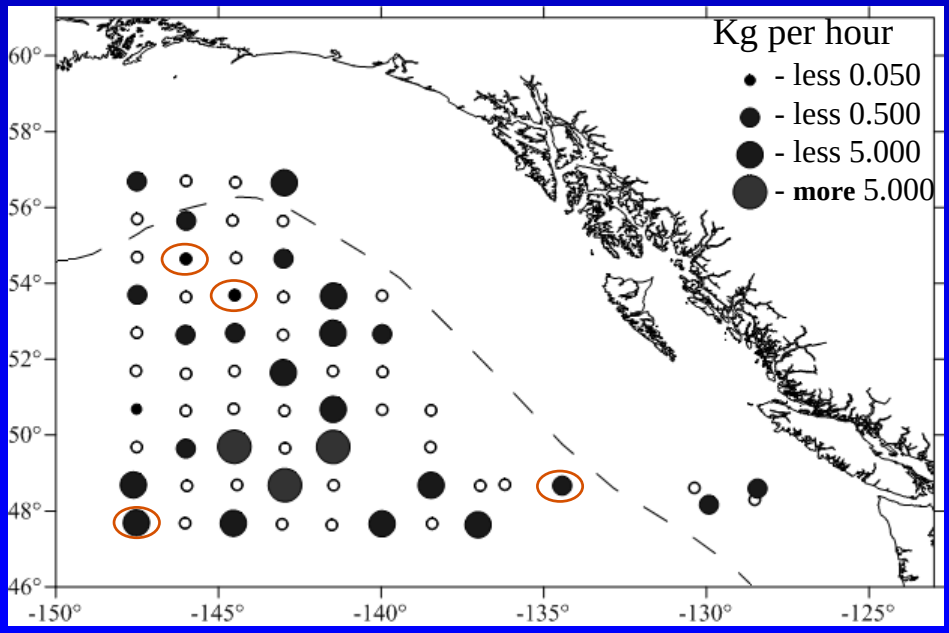
- relate the observed distribution patterns of cephalopods from the trawl survey in the GoA, their occurrence from databases and distribution patterns derived for those species from habitat modeling
- look at the discrepancies between cephalopod distribution patterns from various sources of information
- suggest improvement for data collection to get reliable information on distribution of pelagic cephalopods

Results from epipelagic trawl survey in the GoA in spring 2019

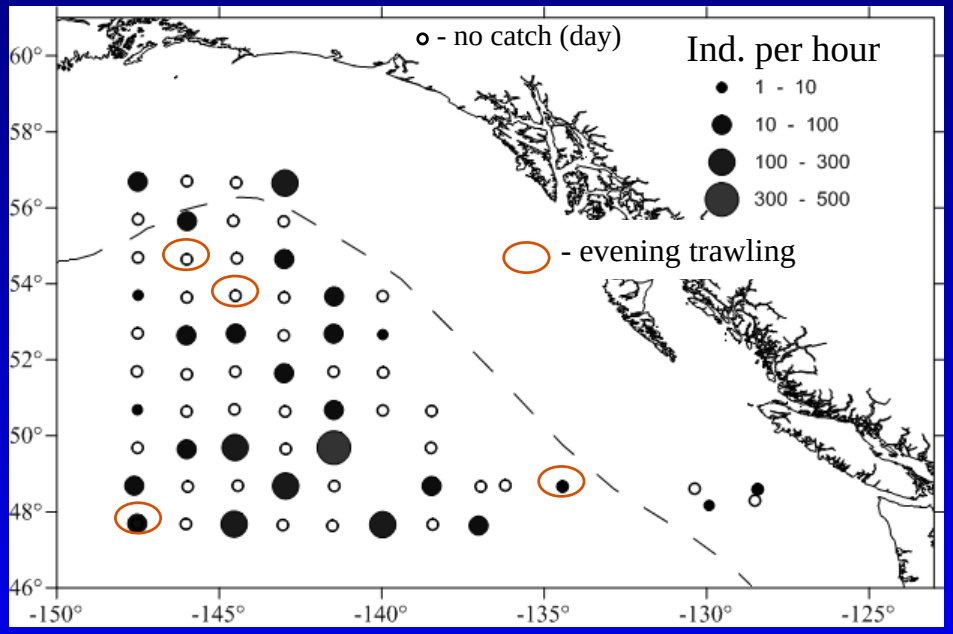
Species	Total occurrence % (64 trawl hauls)	Occurrence at night % (24 trawl hauls)	Occurrence in daytime % (40 trawl hauls)
Boreoteuthis borealis	40.6	100.0	5.0
Gonatus onyx	23.4	58.3	2.5
Gonatus madokai	7.8	16.7	2.5
*Okutania anonycha**	6.3	16.7	---
Onychoteuthis borealijaponica	26.6	66.7	2.5
Onykia (=Moroteuthis) robusta	1.6	4.2	---
Chiroteuthis calyx	7.8	16.7	2.5
Abraliopsis felis	7.8	16.7	---
*Belonella borealis**	4.7	12.5	---
Japetella diaphana	1.6	4.2	---
* - occurrence in fish stomachs			

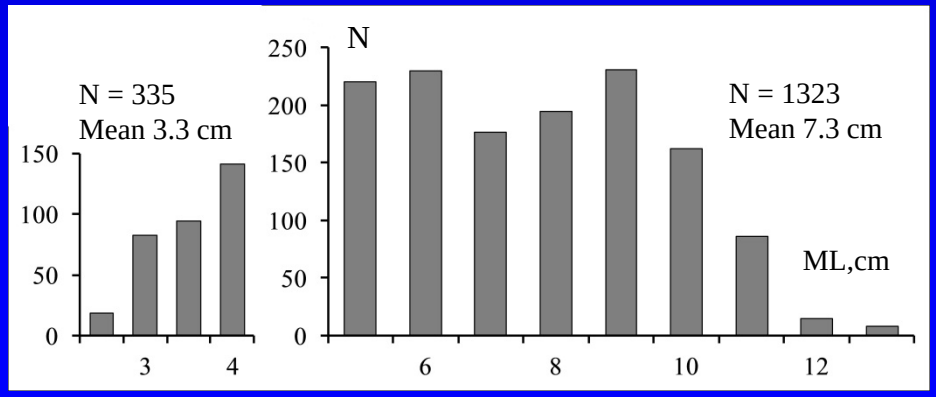
Distribution of cephalopods in the GoA 2019 spring upper epipelagic trawl survey



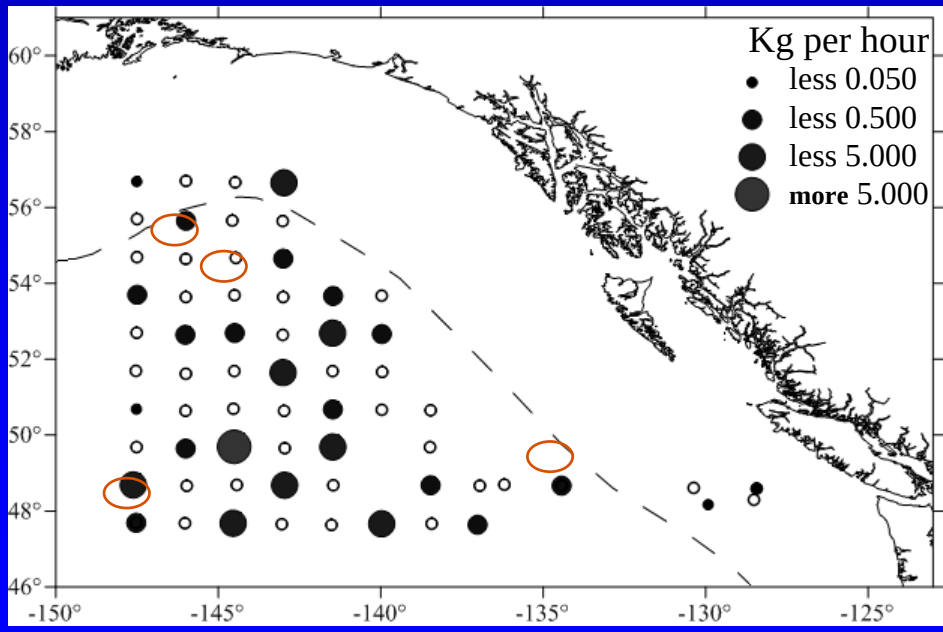


Boreoteuthis borealis

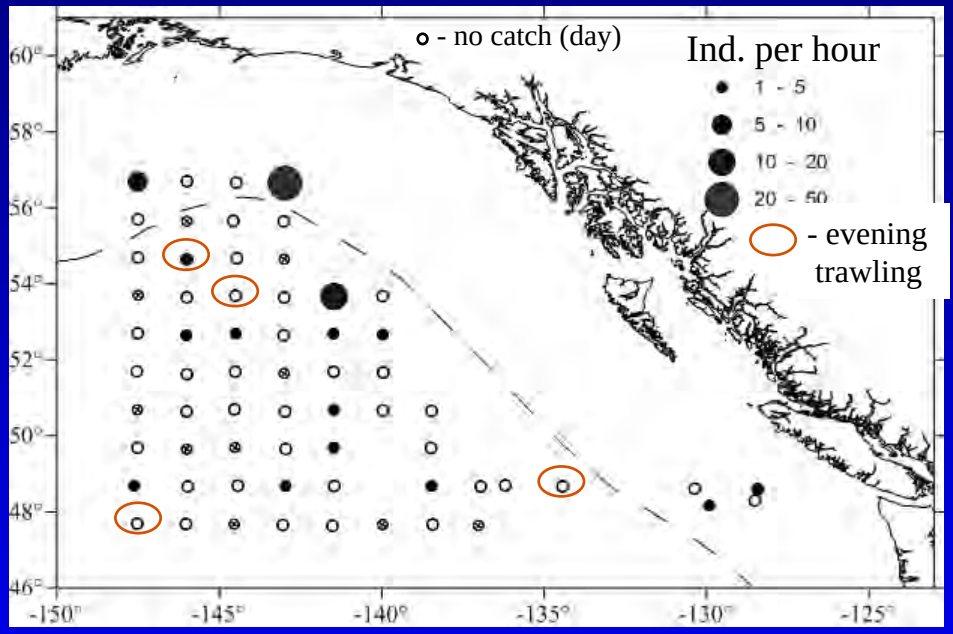


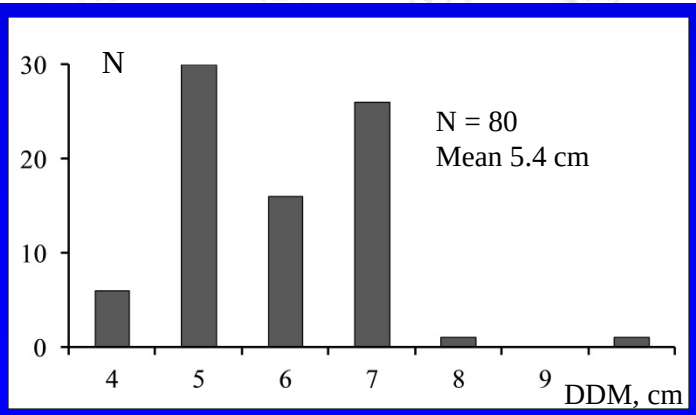


B.borealis – abundant and widely distributed across the research area; individuals were mostly young and immature

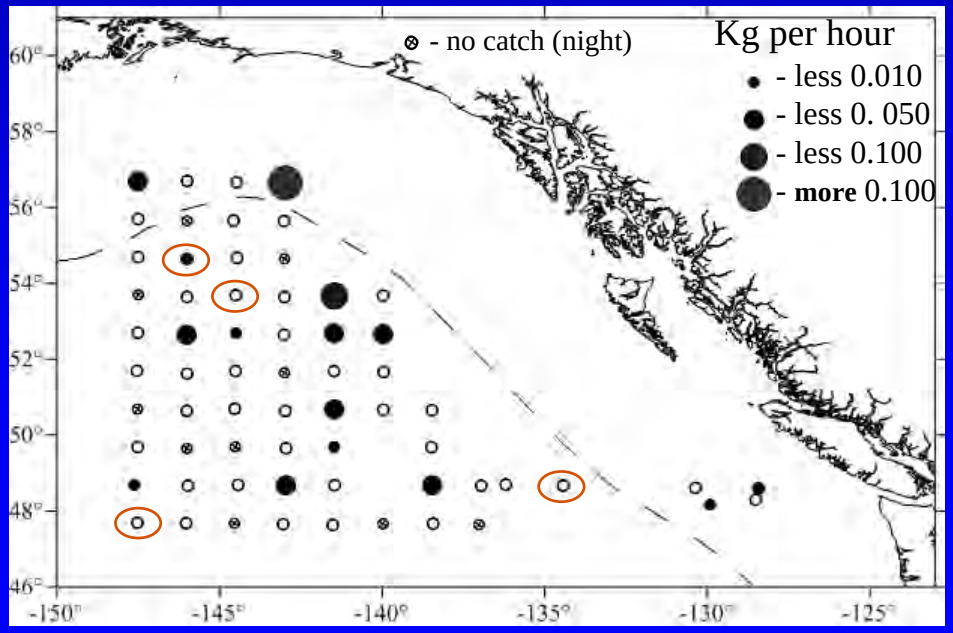


Gonatus onyx

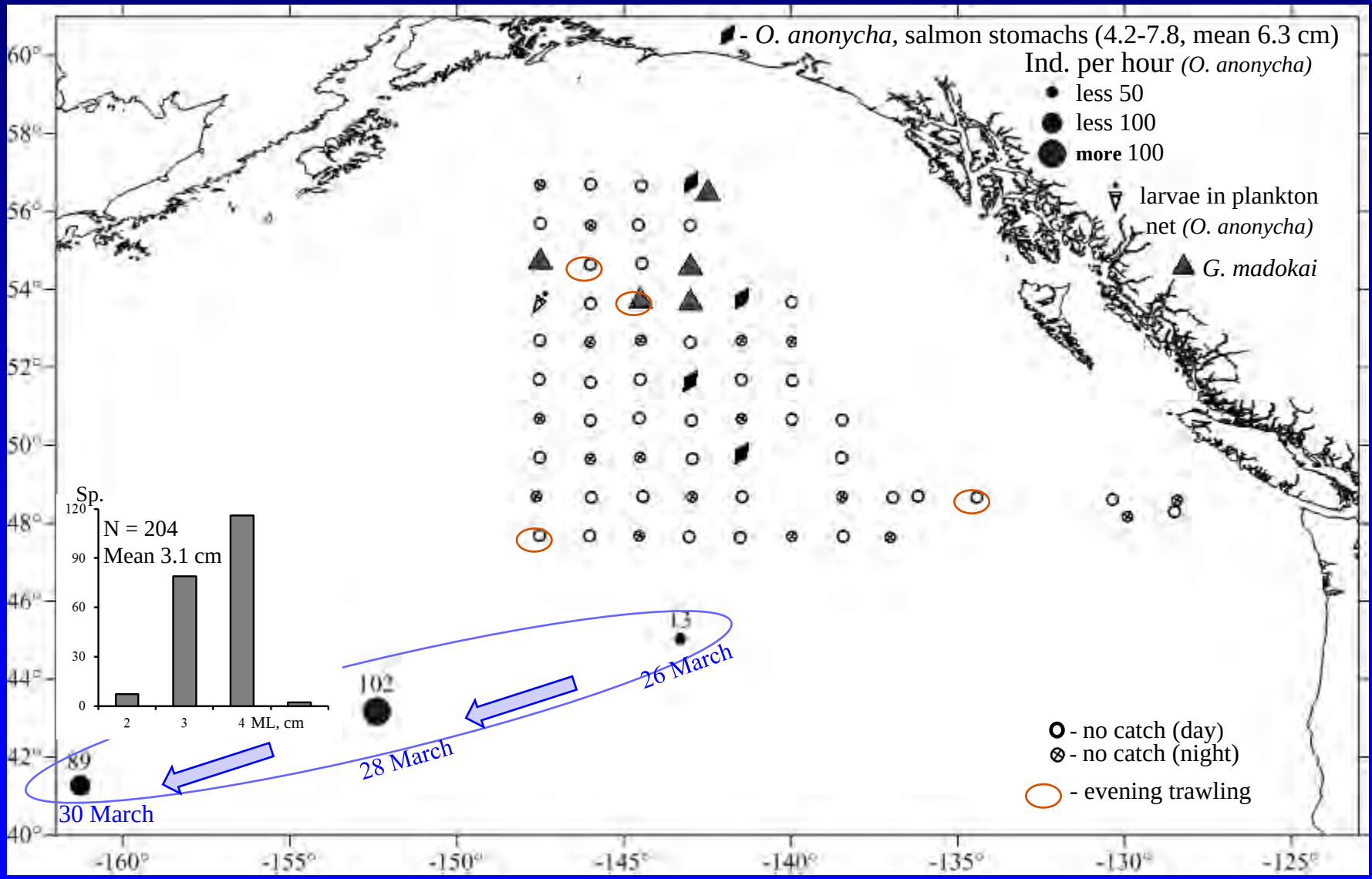




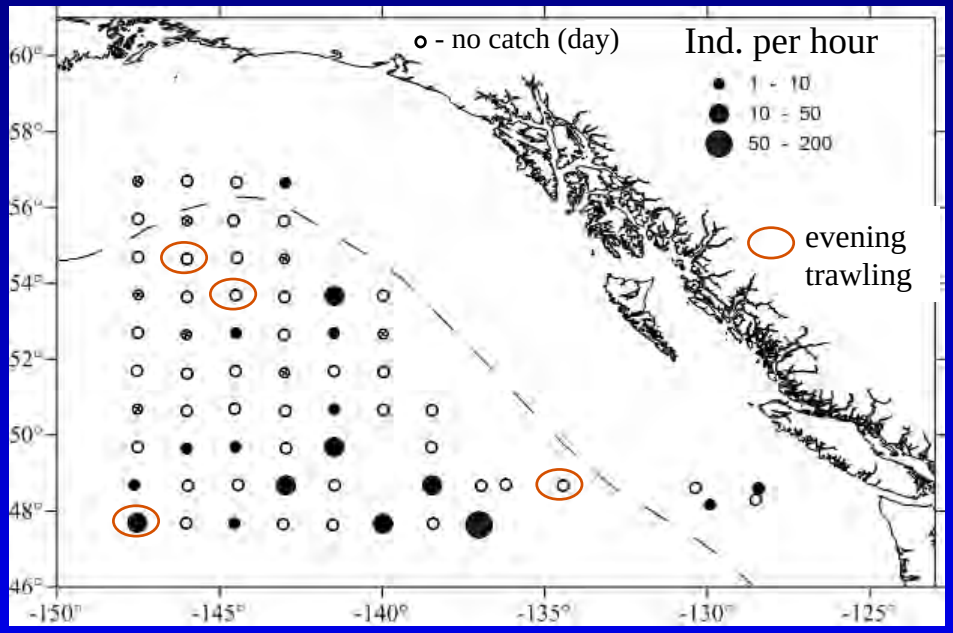
G.onyx also occurred widely across the research area (higher numbers in the northern areas); individuals were mostly young and immature

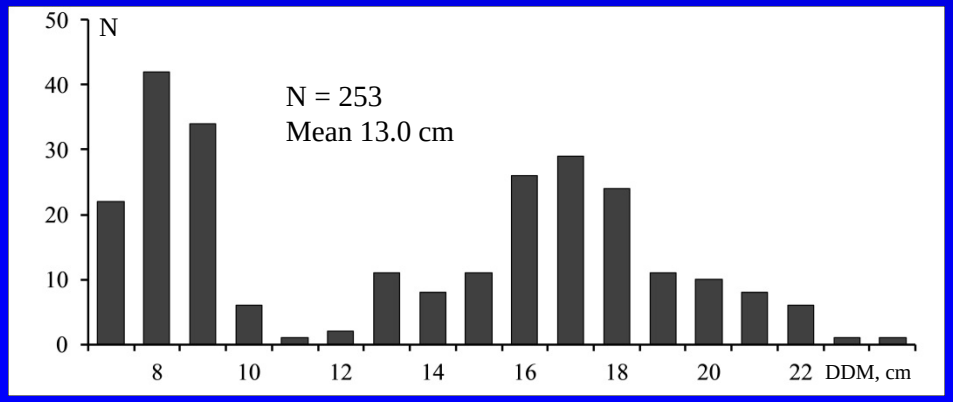


Okutania anonycha and *Gonatus madokai*



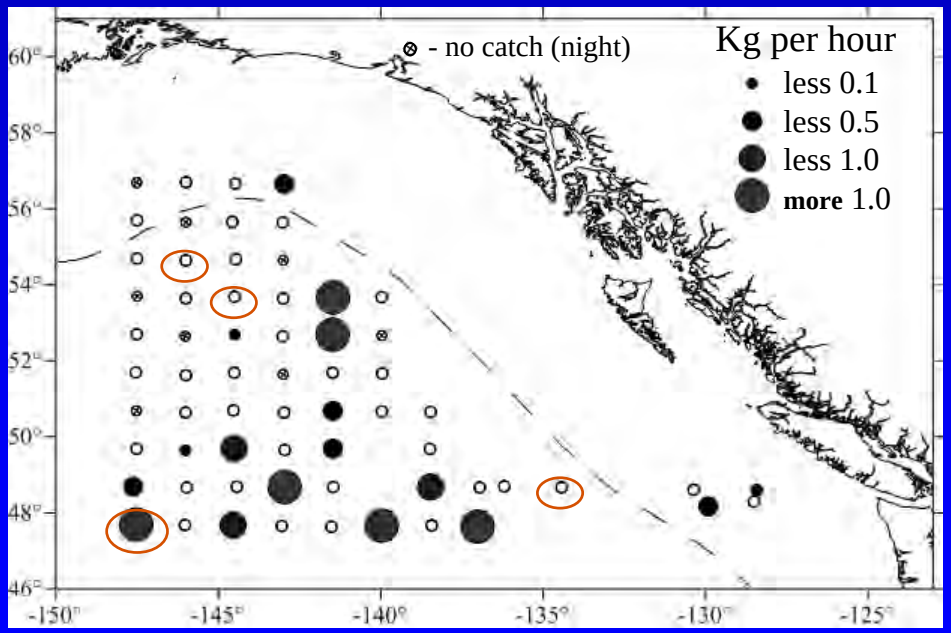
Onychoteuthis borealijaponica



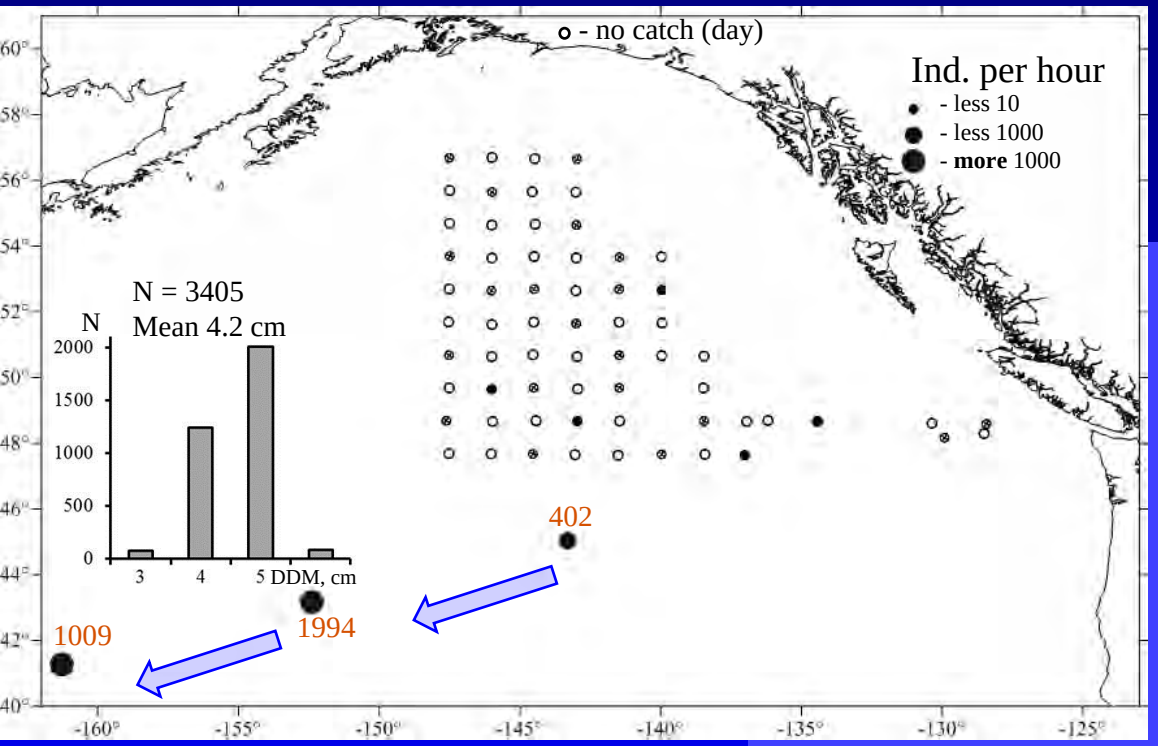


***O.borealijaponica* – abundant, widely distributed over the research area;**

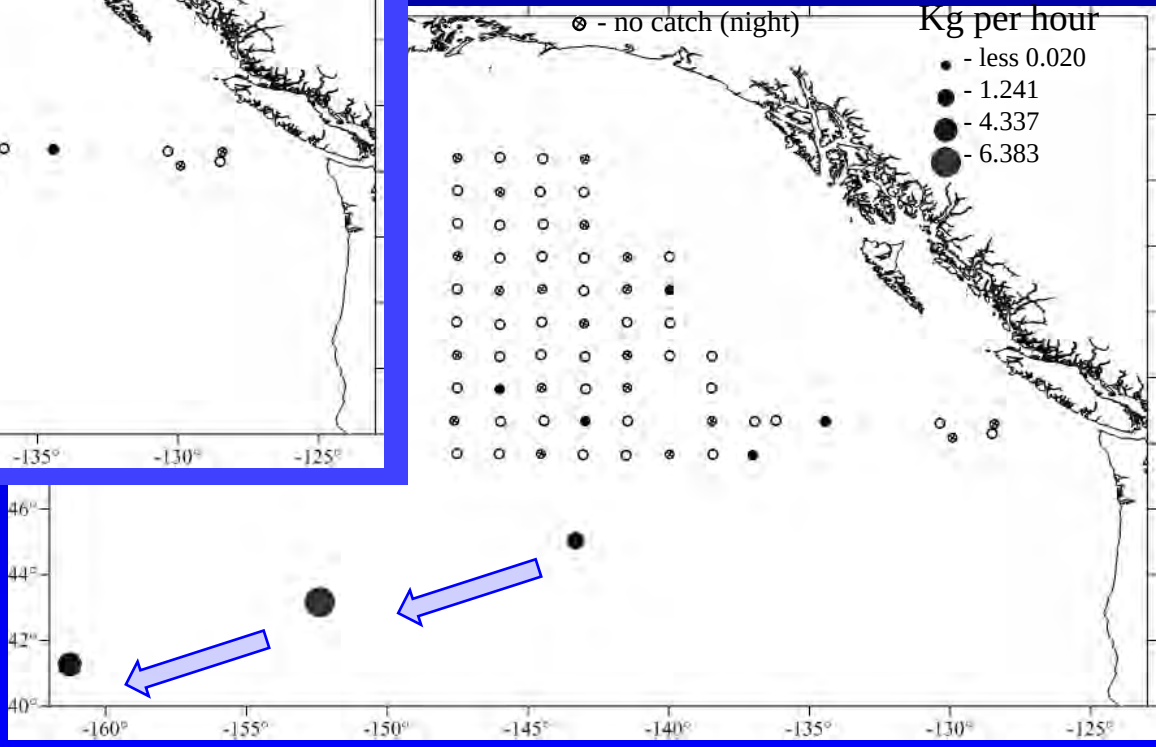
two size groups



Abraliopsis felis

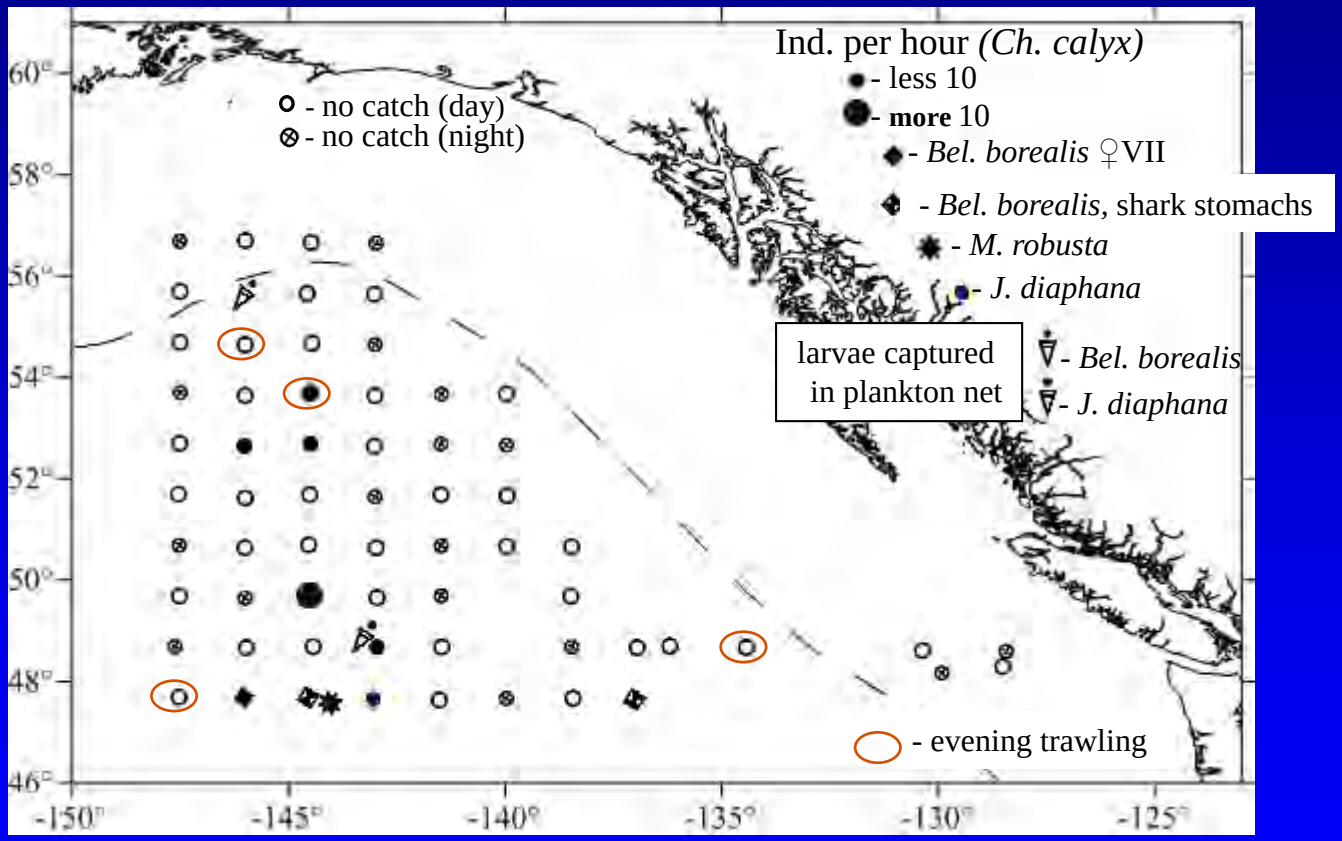


A.*felis* – occasional occurrence over the research area



… higher occurrence beyond the survey area, in the south (on the way back)

Other cephalopods: *Chiroteuthis calyx, Belonella borealis, Mororteuthis robusta* and *Japetella diaphana*



What did the survey show us?

- During 2019 spring trawl survey in the GoA, several abundant pelagic squid were encountered
- Some species were regularly captured and in relatively high numbers (***B.borealils, O.borealijaponica***), some occurred regularly but in small numbers (***G.onyx, A.felis***)
- One potentially abundant species (***O.anonycha***) was absent from trawl catches, and occurred exclusively in salmon stomachs (!!!)

Abundant Squid Species in the NEP

north Boreal
cold water
mesopelagic

family Gonatidae

- ***Okutania anonycha***
- ***Boreoteuthis borealis***
- ***Gonatus onyx***
- ***Gonatus madokai***

south Boreal
warm water
epipelagic

family Enoploteuthidae

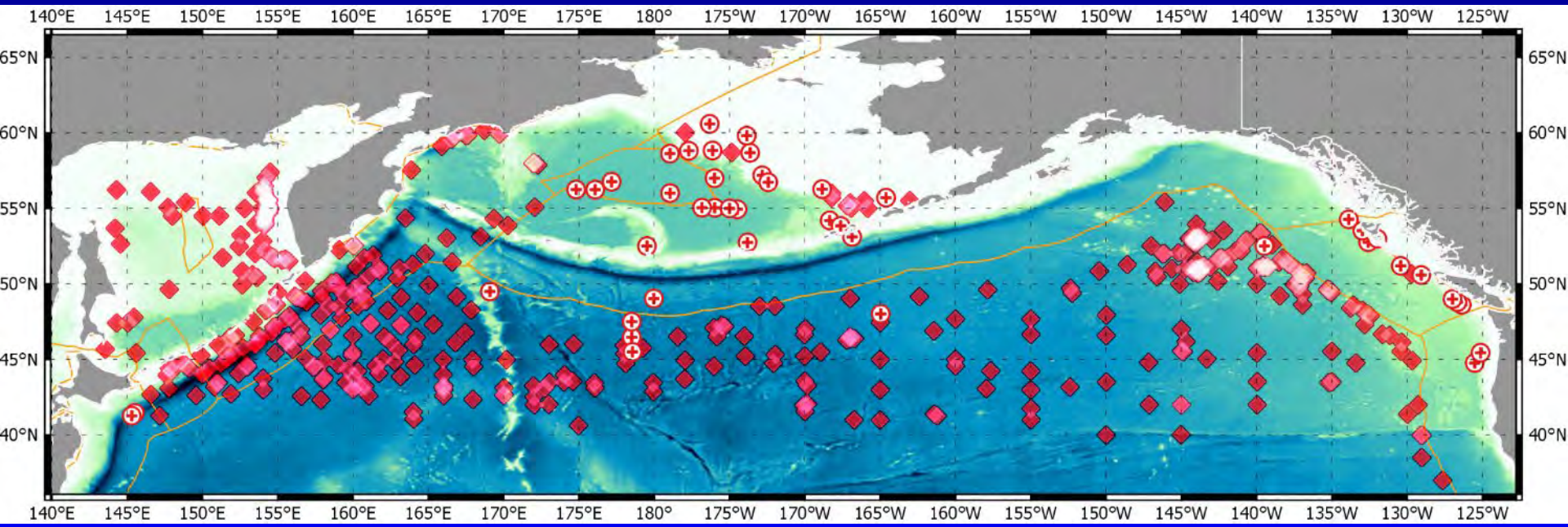
- ***Abraliopsis felis***

family Onychoteuthidae

- ***Onychoteuthis borealijaponica***

Okutania anonycha

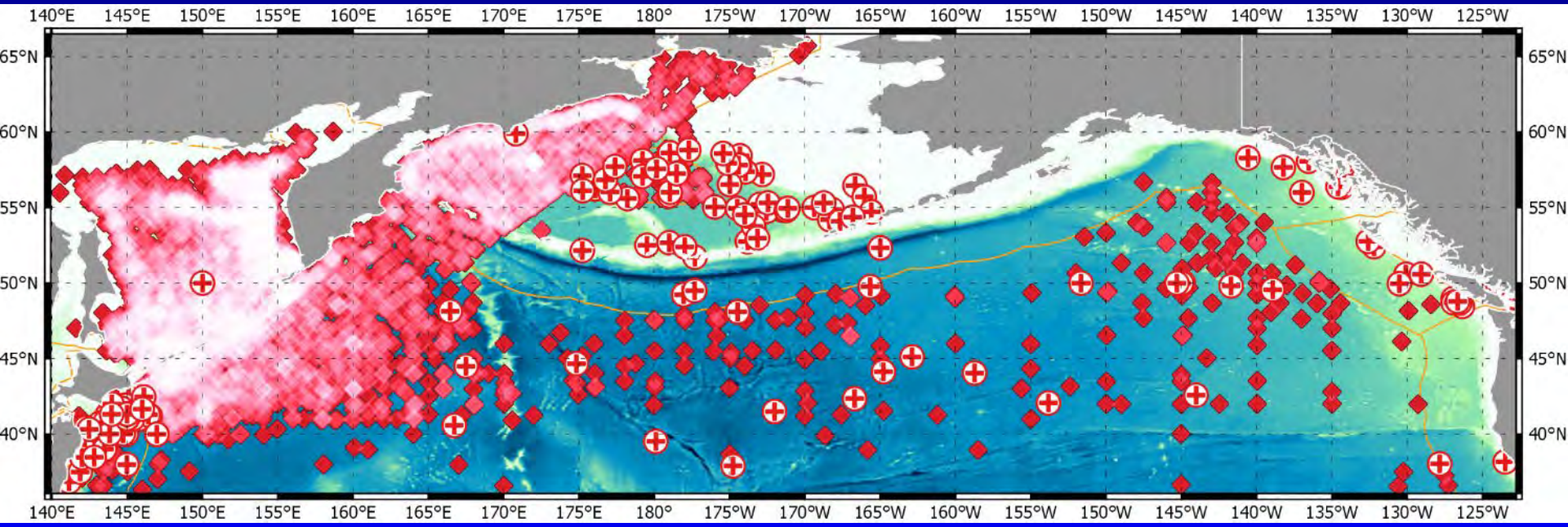
Occurrence based on information from TINRO surveys ◆ and GBIF ⊕



1) widely distributed across the NPO (boreal waters) with high concentrations in the NWPO and NEPO
2) rarely occurred in spring 2019 in GoA (**no catch by surface trawl; rarely occurred in stomachs of sockeye, coho and chinook**)

Boreoteuthis borealis

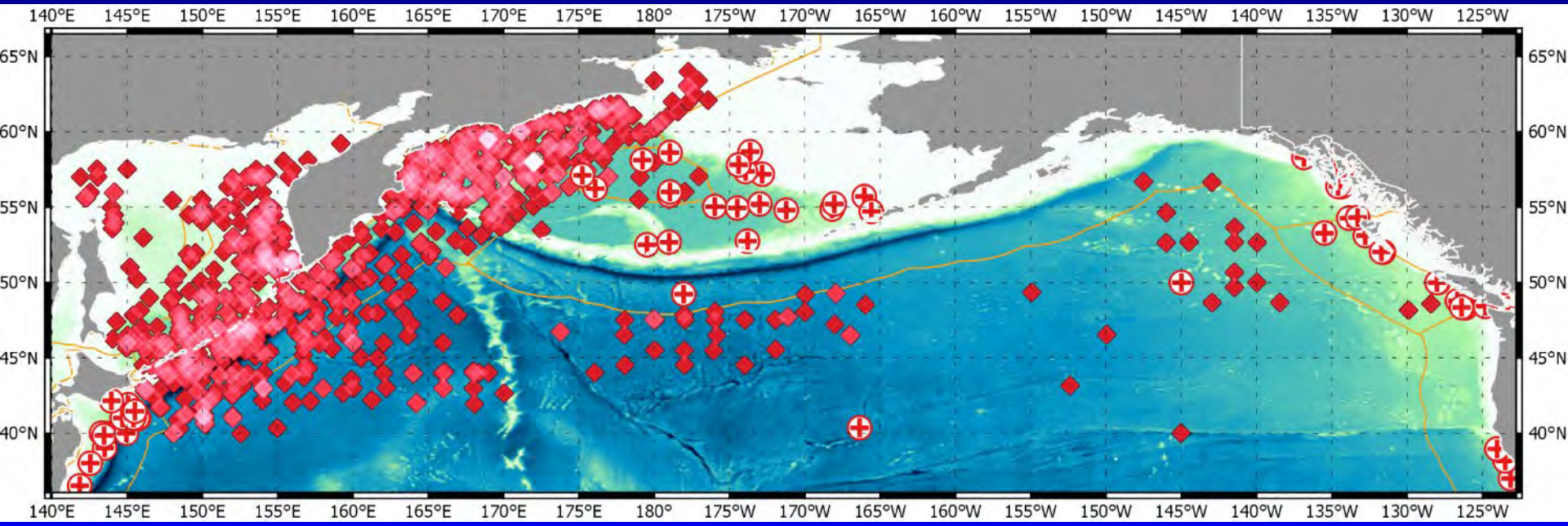
Occurrence based on information from TINRO surveys ◆ and GBIF ⊕



1) widely distributed in the NPO (boreal waters) with high concentrations across the entire range
2) regularly occurred in the 2019 GoA Trawl Survey (in 100% of trawl catches at night; all individuals were immature)

Gonatus onyx

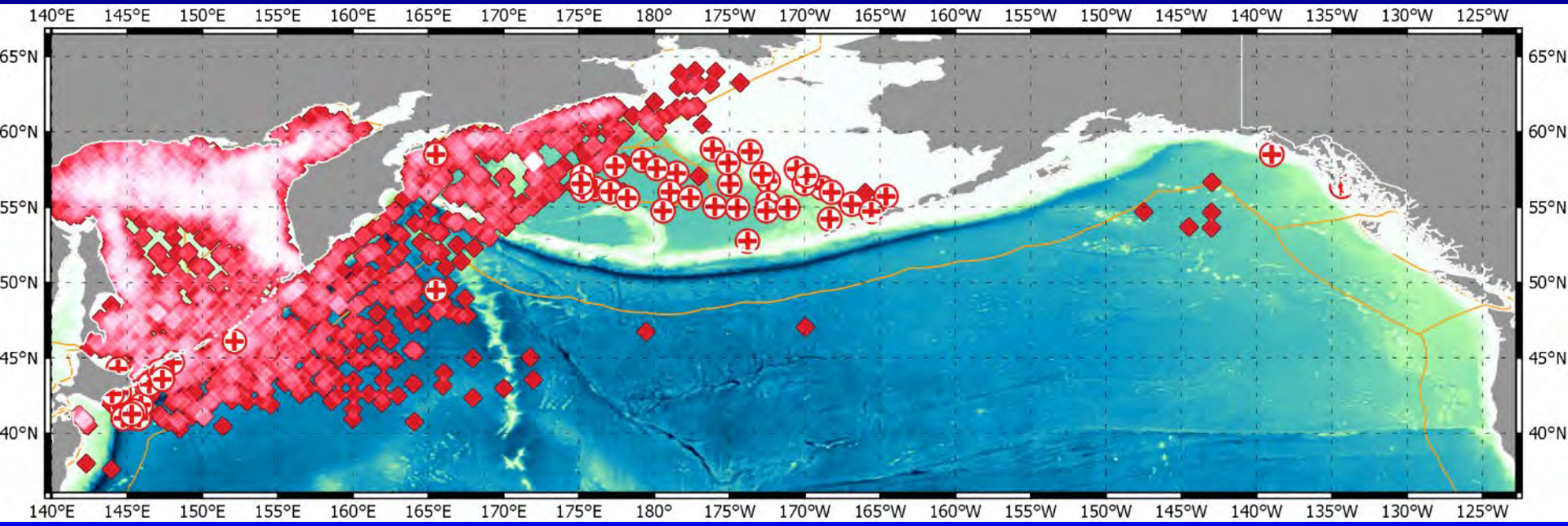
Occurrence based on information from TINRO surveys ◆ and GBIF ⊕



1) widely distributed in the NPO (boreal waters); occur regularly but without any record on high concentrations
2) occasionally occurred in the 2019 GoA Trawl Survey (juveniles and immature; mainly in night hauls)

Gonatus madokai

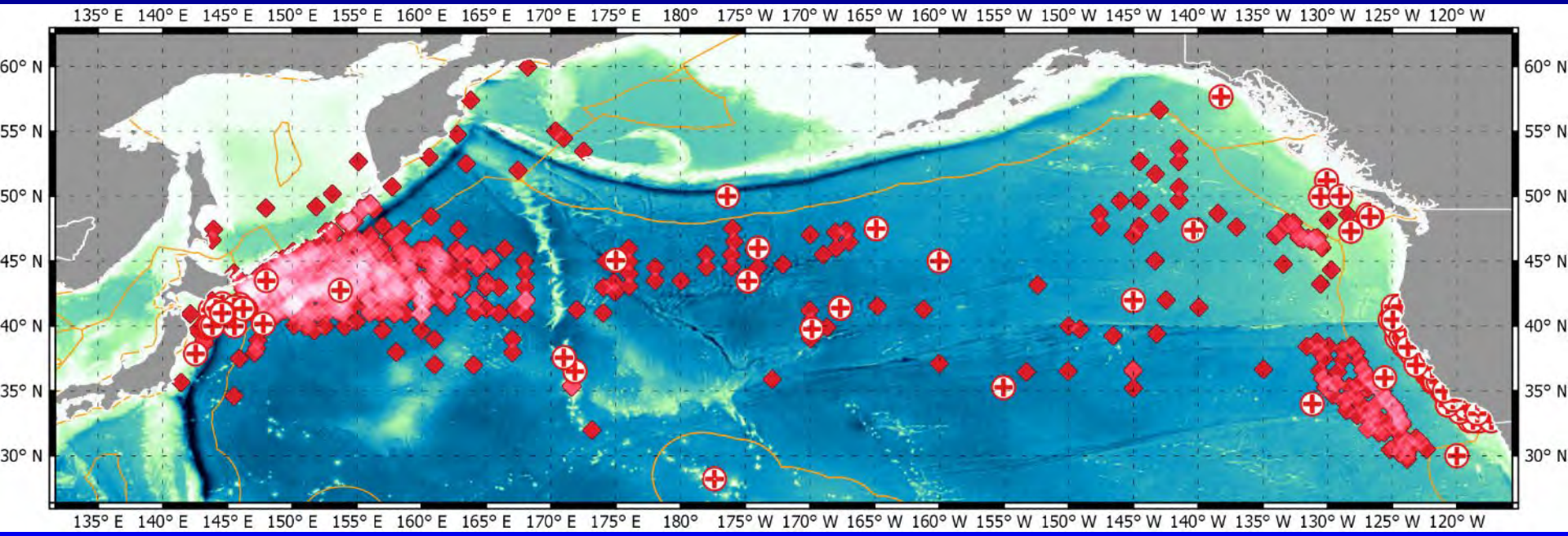
Occurrence based on information from TINRO surveys and GBIF



1) widely distributed in the NWPO (boreal waters); occur regularly;
2) occasionally occurred in the 2019 GoA Trawl Survey (juveniles and immature, mainly north of 53N)

Onychoteuthis borealijaponica

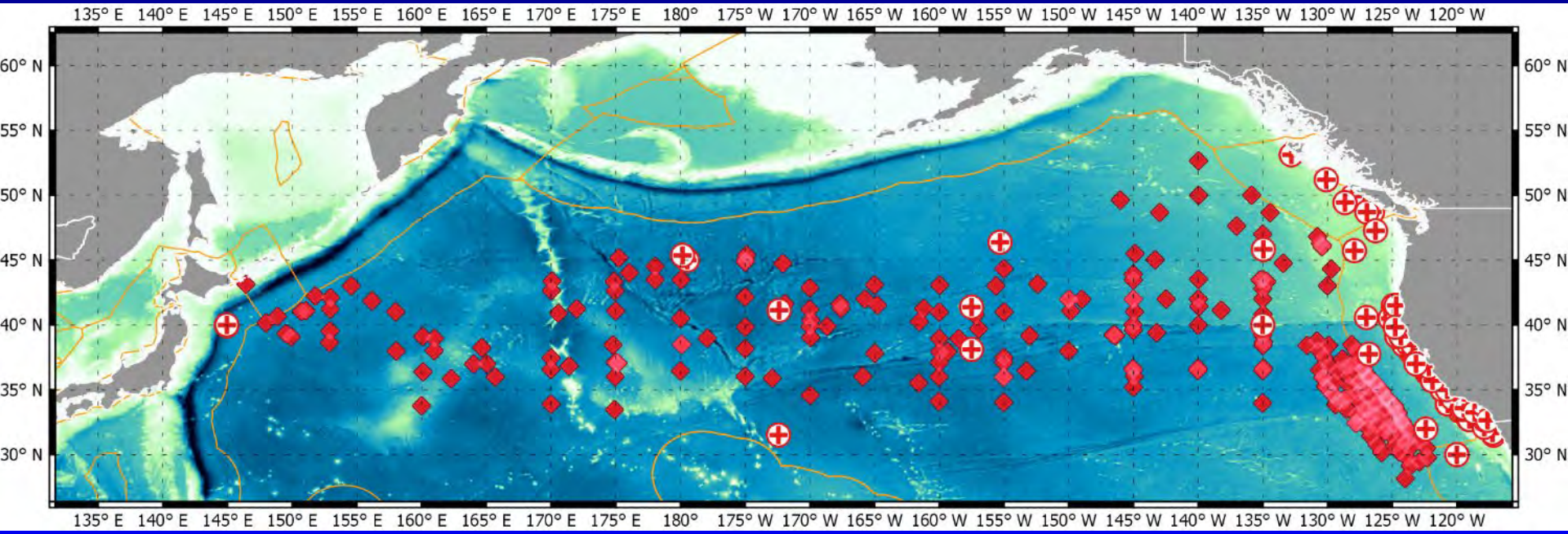
Occurrence based on information from TINRO surveys ◆ and GBIF ⊕



1) widely distributed in the NPO (lower boreal waters and transition zone); occur in high concentrations
2) regularly occurred in the 2019 GoA Trawl Survey (immature and maturing; mainly south of 50N)

Abraliopsis felis

Occurrence based on information from TINRO surveys and GBIF



1) widely distributed in the NPO (subtropical waters and transition zone); occur in high concentrations
2) occasionally occurred in the 2019 GoA Trawl Survey (mature!!! occasionally south of 53N)

Layers to download

Layer	Unit	Max	Mean	Min	Lt. Max	Lt. Min	Range
Temperature	°C	☐	☐	☐	☐	☐	☐
Salinity	PSS	☐	☐	☐	☐	☐	☐
Currents velocity	m-1	☐	☐	☐	☐	☐	☐
Ice thickness	m	☐	☐	☐	☐	☐	☐
Sea ice concentration	Fraction	☐	☐	☐	☐	☐	☐
Nitrate	mol.m-3	☐	☐	☐	☐	☐	☐
Phosphate	mol.m-3	☐	☐	☐	☐	☐	☐
Silicate	mol.m-3	☐	☐	☐	☐	☐	☐
Dissolved molecular oxygen	mol.m-3	☐	☐	☐	☐	☐	☐
Iron	umol.m-3	☐	☐	☐	☐	☐	☐
Chlorophyll	mg.m-3	☐	☐	☐	☐	☐	☐
Phytoplankton	umol.m-3	☐	☐	☐	☐	☐	☐
Primary productivity	g.m-3.day-1	☐	☐	☐	☐	☐	☐
Calcite	mol.m-3		☐				
pH	-		☐				
Photosynt. Avail. Radiation	E.m-2.day-1	☐					
Diffuse attenuation	m-1						
Cloud cover	%						

Select All Layers ☐

* Lt. for average of the minimum and maximum records

Geophysical and Biotic Factors

Link squid distribution data to abiotic and biotic factors that is supposed to be associated with squid occurrence

bio-oracle.org

set of layers for marine environmental parameters

The data available in Bio-ORACLE are documented in two peer reviewed articles that you should cite:

Tyberghein L, Verbruggen H, Pauly K, Troupin C, Mineur F, De Clerck O (2012) Bio-ORACLE: A global environmental dataset for marine species distribution modelling. Global Ecology and Biogeography, 21, 272–281.
[access publication] [supporting information]

Assis, J., Tyberghein, L., Bosh, S., Verbruggen, H., Serrão, E. A., & De Clerck, O. (2017). Bio-ORACLE v2.0: Extending marine data layers for bioclimatic modelling. Global Ecology and Biogeography.
[access publication] [supporting information]

dissox
sstmean
sstrange
bathymean
curvelltmax_bdmax
curvelltmax_bdmean
curvelltmax_bdmin
curvelltmin_bdmax
curvelltmin_bdmean
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dissoxltmax_bdmax
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templtmax_bdmax
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templtmin_bdmean
templtmin_bdmin
carbonphytoltmax_bdmax
carbonphytoltmax_bdmean
carbonphytoltmax_bdmin
carbonphytoltmin_bdmax
carbonphytoltmin_bdmean
carbonphytoltmin_bdmin
templtmax_ss
templtmin_ss
tempmean_ss
temprange_ss
curvelmax_ss
curvelmean_ss
curvelmin_ss
curvelrange_ss

Of the total 320, we selected 48 variables, that were not strongly correlated with each other

curvelltmax_ss
curvelltmin_ss
dissoxmean_ss
dissoxrange_ss
dissoxltmax_ss
dissoxltmin_ss
carbonphytomax_ss
carbonphytomean_ss
carbonphytomin_ss
carbonphytorange_ss
carbonphytoltmax_ss
carbonphytoltmin_ss

	Species					
V	anonycha	borealijaponica	borealis	felis	madokai	onyx
templtmin_ss	2.12	37.30	1.11	76.50	15.17	5.40
bathymean	1.45	1.40	53.31	1.20	2.99	11.50
templtmax_ss	2.44	29.20	0.29	0.10	0.00	4.50
sstmean	19.68	0.00	0.17	0.00	0.00	4.70
carbonphytomin_ss	5.42	0.30	0.97	1.20	10.43	6.10
dissoxltmax_ss	4.58	9.40	3.06	0.00	1.84	2.90
templtmin_bdmin	11.35	0.20	0.06	0.00	8.33	0.60
carbonphytoltmin_bdmin	0.42	0.30	0.00	0.10	16.66	2.50
sstrange	5.77	5.10	1.07	0.50	2.38	4.90
dissoxrange_ss	10.88	0.50	2.45	0.00	4.73	0.40
curvelltmin_bdmin	6.22	0.40	8.17	0.40	3.09	0.50
tempmean_ss	0.00	0.00	0.00	14.00	0.63	0.10
dissoxmean_ss	0.04	0.00	0.00	0.40	0.00	11.50
templtmax_bdmax	0.00	2.80	3.86	0.00	3.76	0.00
carbonphytoltmin_ss	3.27	2.50	2.94	0.10	0.93	0.20
carbonphytoltmax_bdmin	1.90	0.00	0.39	0.10	0.74	6.10
templtmax_bdmin	0.08	1.00	0.00	0.00	5.00	2.70
dissoxltmin_bdmax	0.37	0.00	8.10	0.00	0.00	0.20
curvelltmin_bdmean	1.22	0.20	1.73	0.60	2.77	1.60
carbonphytoltmax_bdmean	0.27	0.00	0.06	0.00	0.05	7.40
dissoxltmin_bdmean	0.00	2.40	0.37	0.00	1.79	3.00
curvelltmax_bdmax	3.49	0.30	0.06	0.10	0.32	2.50
dissoxltmin_bdmin	1.48	0.20	2.91	0.50	1.33	0.00
carbonphytomean_ss	0.60	1.00	0.00	0.10	1.50	2.90
carbonphytorange_ss	4.53	0.10	0.00	0.00	0.04	1.20
curvelltmin_ss	0.26	0.70	0.61	0.40	2.79	0.90
templtmin_bdmean	0.63	0.00	0.00	0.00	0.00	4.30
dissoxltmax_bdmax	0.66	0.00	1.87	0.00	0.00	2.40
curvelmax_ss	1.43	0.70	1.19	0.00	0.00	1.00
curvelmin_ss	2.14	0.10	0.00	0.10	0.73	1.10
curvelltmax_bdmin	1.28	0.20	0.00	1.20	0.78	0.70
curvelltmin_bdmax	0.00	0.40	0.83	0.40	0.95	1.30
templtmax_bdmean	0.00	0.10	0.00	0.00	3.47	0.20
temprange_ss	1.36	0.00	0.00	1.10	1.05	0.00
dissox	0.23	0.20	2.75	0.00	0.00	0.10
curvelmean_ss	0.00	0.80	0.00	0.30	1.89	0.20
carbonphytoltmax_ss	0.76	0.00	0.00	0.00	0.51	1.50
templtmin_bdmax	0.83	0.00	0.00	0.00	0.58	0.80
carbonphytomax_ss	0.22	0.10	0.00	0.40	1.25	0.20

Machine learning was based on squid occurrence and absence (no catch) in a trawl haul
(training sample included 80% of observations, and test sample 20%)

Judging from the values of permutations (PI):

1) for Gonatid squid, SST values were less important, and Carbon values expressed via phytoplankton were more important

2) for *A. felis* and *O.borealijaponica* SST values were more important than other analyzed factors

Then we dropped (removed) variables until all of them had permutation importance (PI) greater than 0.5% for each species

AUC (Area Under Curve value) didn't change much, but the number of variables decreased to

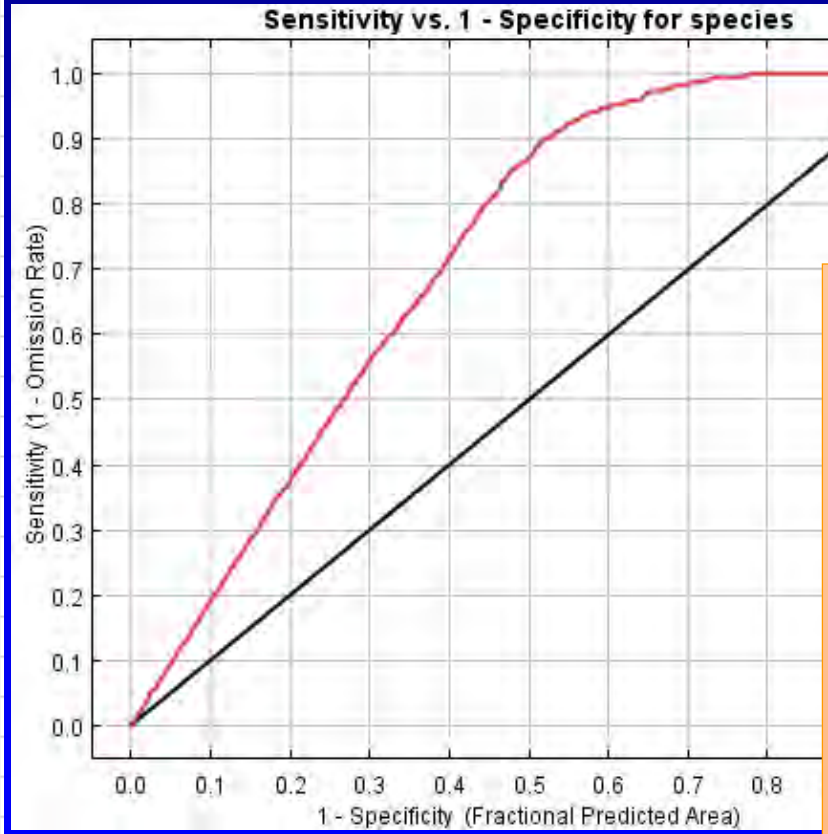
O. anonycha – 17
O. borealijaponica – 23
B. borealis – 18
A. felis – 18
G. madokai – 24
G. onyx – 30

All sets of selected variables were different for each species

Finally, we estimated PI and contribution of a variable (VI) in a full set for those variables which had PI > 0.5% during training

Species	anonycha	
V	VI	PI
carbonphytoltmax_bdmin	46.8	0.5
templtmin_ss	19.4	2
dissoxltmax_ss	9.0	6.3
templtmin_bdmin	7.0	14.4
carbonphytorange_ss	3.0	3.8
carbonphytoltmax_ss	2.2	8
carbonphytomin_ss	1.8	1.5
curvelltmin_bdmin	1.6	4.4
curvelmax_ss	1.3	5.1
sstmean	1.2	14.9
templtmax_ss	1.1	3.7
carbonphytoltmin_ss	1.1	6.4
dissoxrange_ss	0.9	0.3
curvelltmax_bdmin	0.7	0
carbonphytoltmax_bdmax	0.6	6.1
sstrange	0.5	0.3
bathymean	0.4	15.8
dissoxltmin_bdmin	0.3	1.7
templtmin_bdmean	0.2	1.8
curvelrange_ss	0.2	0.4
carbonphytomean_ss	0.2	0.7
curvelltmax_bdmax	0.1	0.4
curvelltmin_bdmean	0.1	0.2
temprange_ss	0.1	0.5
curvelmin_ss	0.1	0.6
templtmin_bdmax	0.0	0
dissoxltmax_bdmax	0.0	0

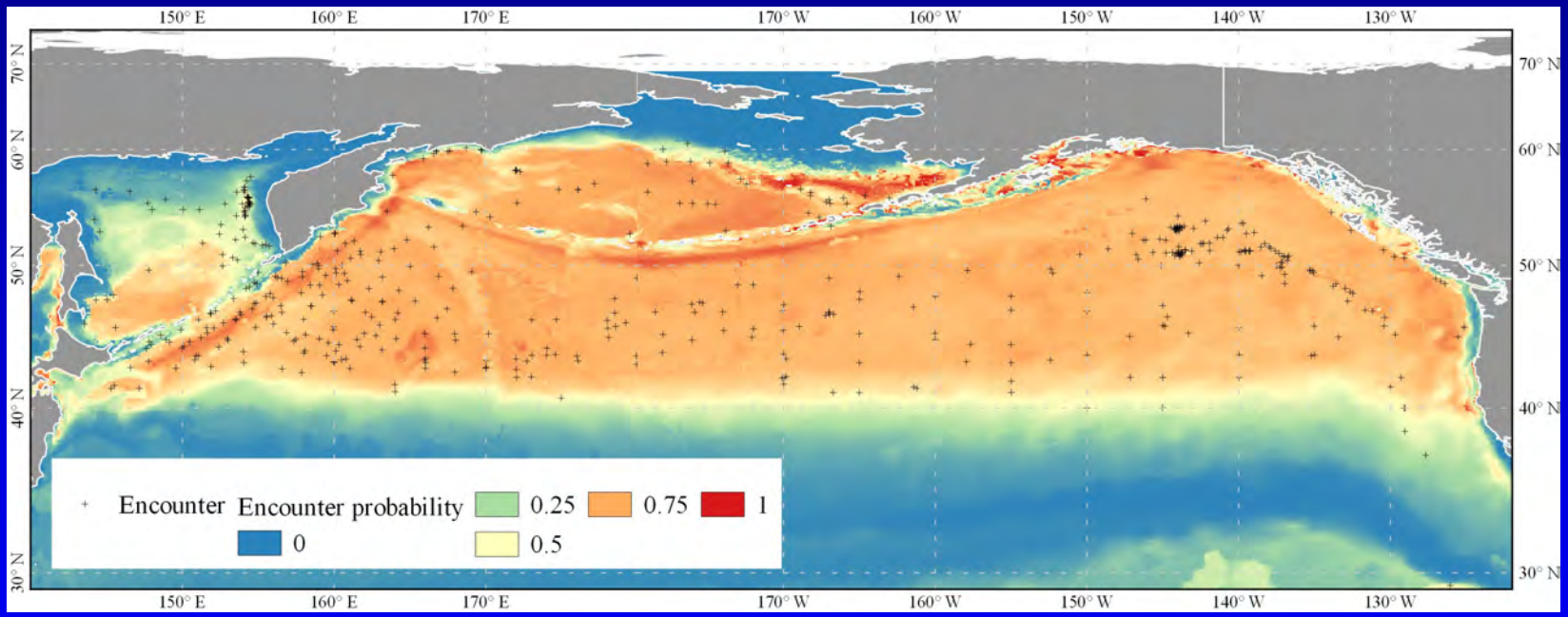
Okutania anonycha



TEST AUC = 0.85 (trapezoidal)
Accuracy : 0.7794
95% CI : (0.7162, 0.8343)
No Information Rate : 0.5
P-Value [Acc > NIR] : < 2.2e-16
#
Kappa : 0.5588
#
Mcnemar's Test P-Value : 0.0003466
#
Sensitivity : 0.9020
Specificity : 0.6569
Pos Pred Value : 0.7244
Neg Pred Value : 0.8701
Prevalence : 0.5000
Detection Rate : 0.4510
Detection Prevalence : 0.6225
Balanced Accuracy : 0.7794

Okutania anonycha

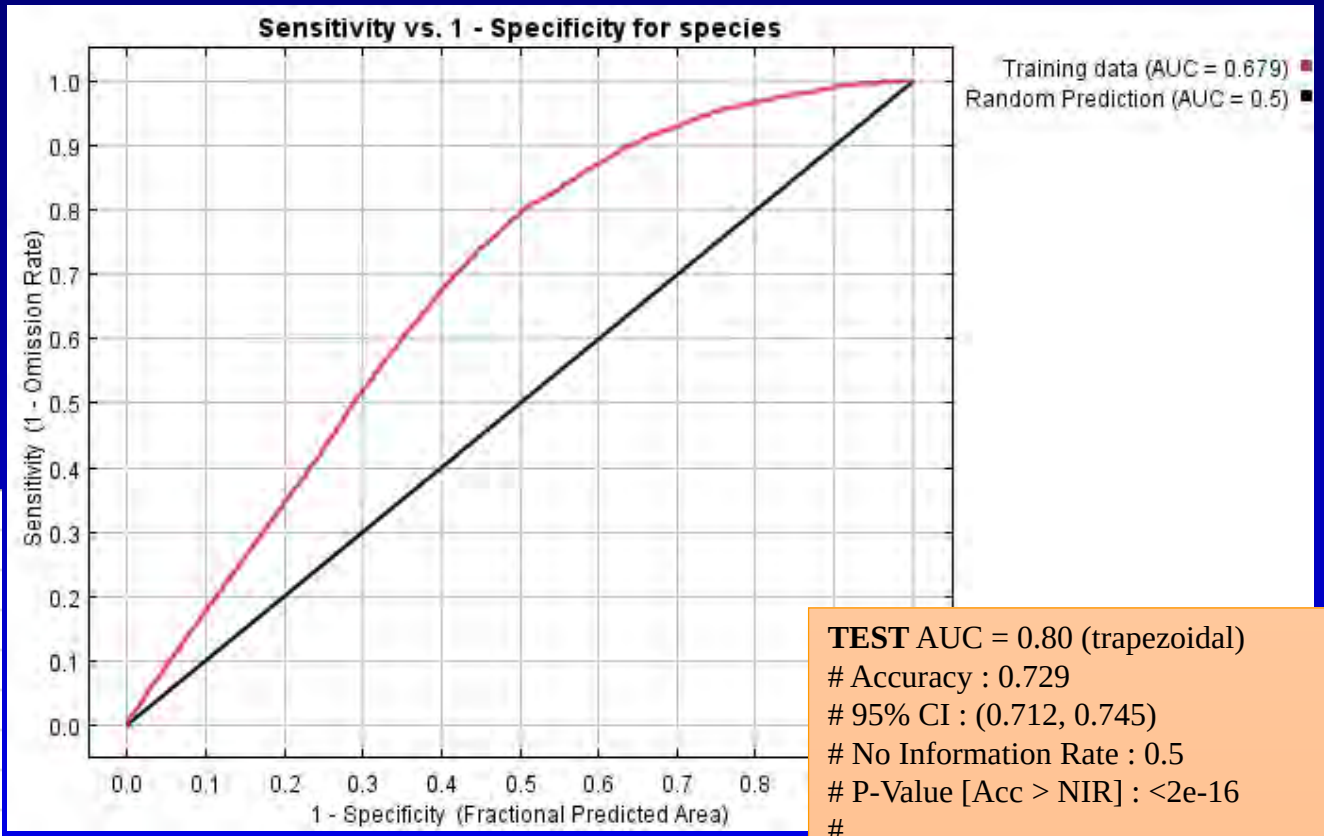
Occurrence and Encounter Probability based on abiotic and biotic factors from Bio-Oracle



1) relatively even encounter probability in the NPO

2) increased probability along the island chains

Boreoteuthis borealis

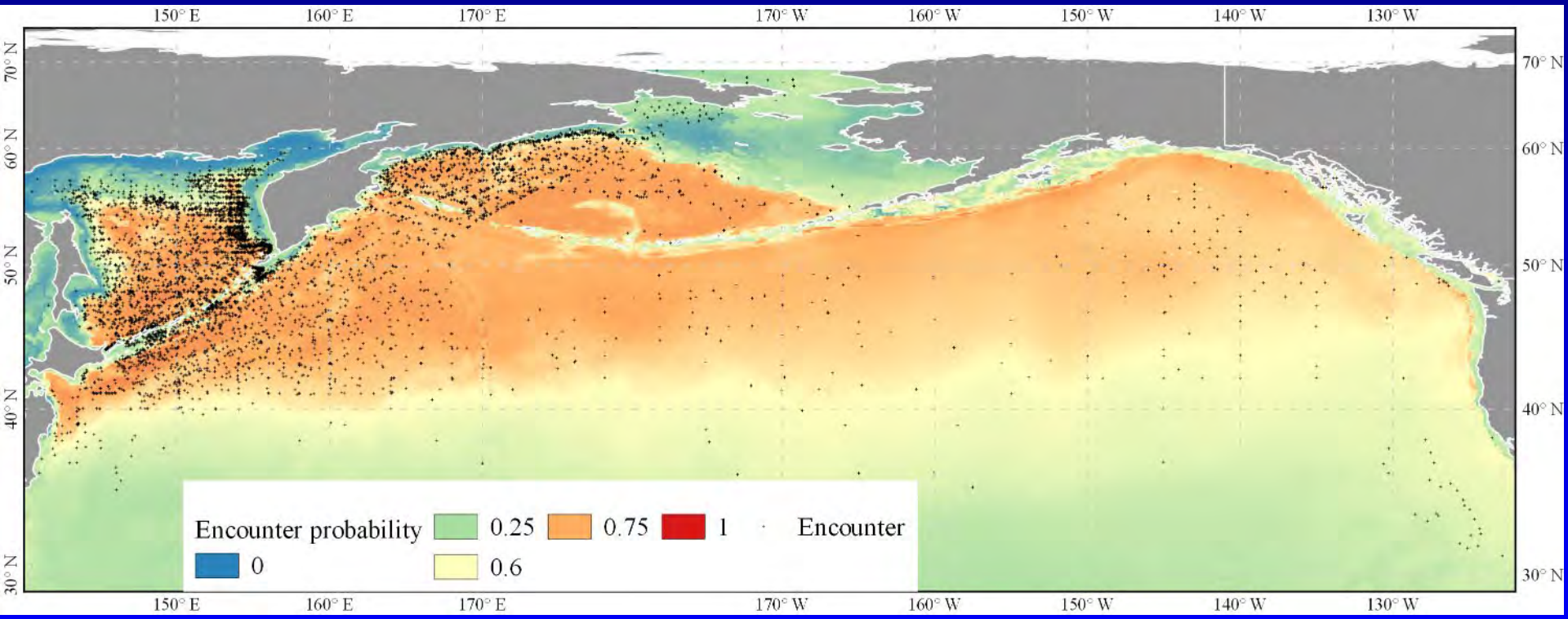


Species	borealis	
V	VI	PI
carbonphytoltmax_bdmean	39.6	2.9
templtmin_ss	14.9	1.6
dissoxltmax_bdmax	13.1	5.6
templtmax_bdmax	6.4	7.7
dissox	5.8	1.7
curvelltmin_bdmin	4.4	6.8
bathymean	4.3	64.2
dissoxltmin_bdmin	1.8	0.1
curvelltmax_ss	1.7	2.7
carbonphytoltmin_ss	1.6	0.6
curvelltmin_bdmean	1.6	0.4
dissoxltmax_ss	1.0	1.2
dissoxltmin_bdmean	0.9	0.5
sstrange	0.8	2.2
dissoxltmin_bdmax	0.8	1.1
curvelmax_ss	0.7	0.1
carbonphytomin_ss	0.4	0.5
dissoxrange_ss	0.3	0.2

TEST AUC = 0.80 (trapezoidal)
Accuracy : 0.729
95% CI : (0.712, 0.745)
No Information Rate : 0.5
P-Value [Acc > NIR] : <2e-16
#
Kappa : 0.458
#
Mcnemar's Test P-Value : 0.229
#
Sensitivity : 0.741
Specificity : 0.717
Pos Pred Value : 0.723
Neg Pred Value : 0.735
Prevalence : 0.500
Detection Rate : 0.371
Detection Prevalence : 0.512
Balanced Accuracy : 0.729

Boreoteuthis borealis

Occurrence and Encounter Probability based on abiotic and biotic factors from Bio-Oracle



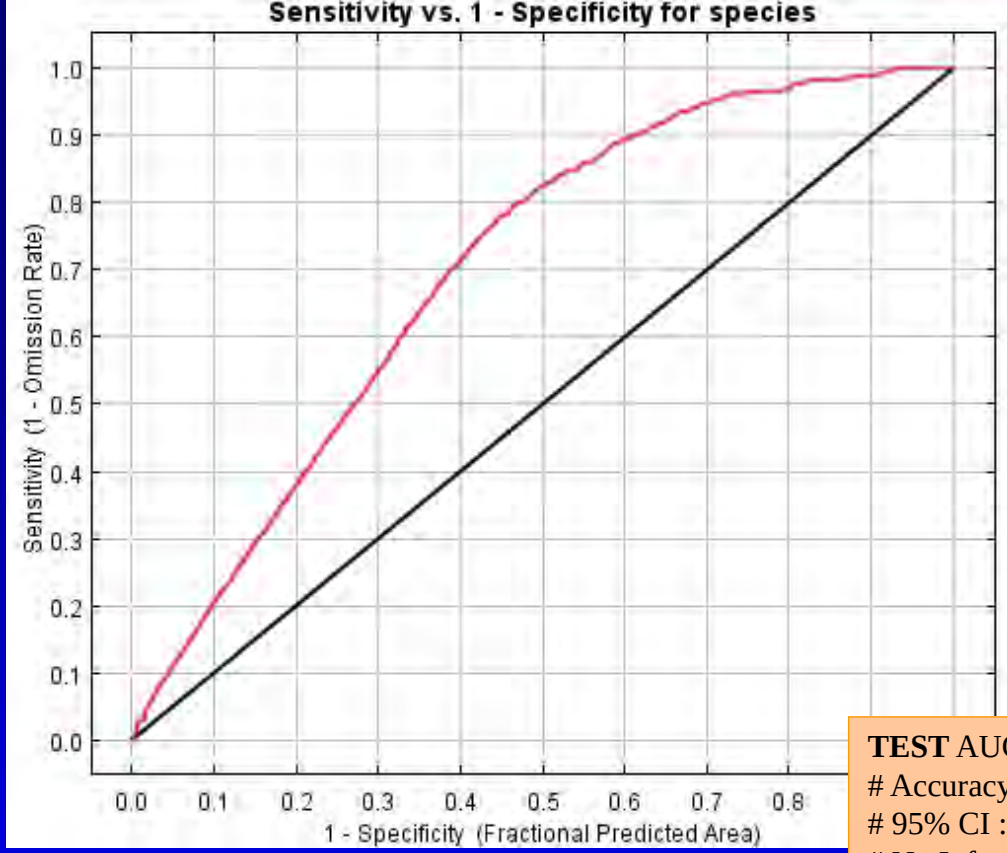
1) **higher probability in the NWPO compared to NEPO**

2) **high probability in the Okhotsk Sea**

Gonatus onyx

Species	onyx

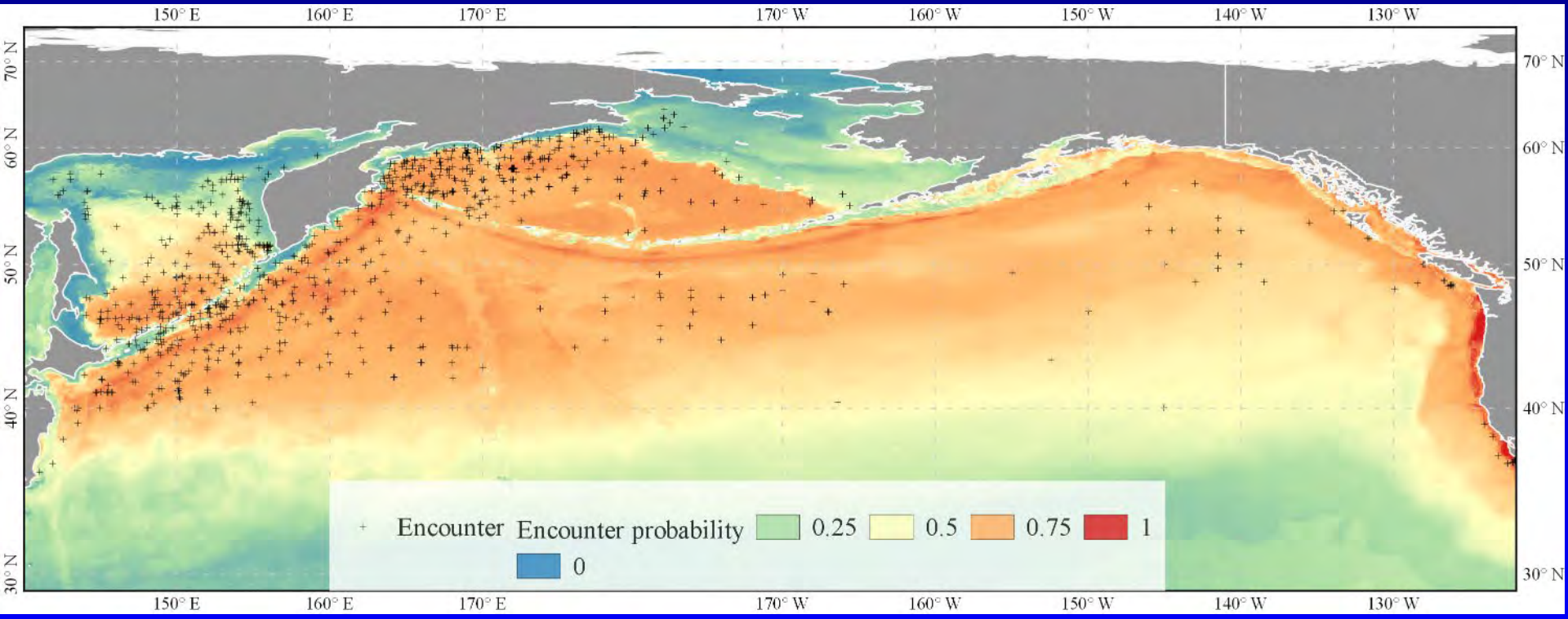
V	VI	PI
carbonphytoltmax_bdmean	56.3	4.4
bathymean	10.8	50.1
carbonphytoltmin_bdmin	10.8	0
templtmin_ss	7.2	2.9
carbonphytoltmax_bdmax	3.2	0
carbonphytomean_ss	2.0	2.5
templtmax_bdmin	1.7	1.2
sstmean	1.6	12.8
carbonphytorange_ss	0.9	4.2
curvelltmin_bdmean	0.8	0.9
templtmax_ss	0.8	0.1
templtmin_bdmax	0.7	4
sstrange	0.7	0
dissoxltmax_ss	0.6	0.2
curvelltmin_bdmin	0.3	4.7
dissoxmean_ss	0.3	5.3
dissoxltmin_bdmean	0.3	1.2
dissoxltmax_bdmin	0.2	0.7
dissoxltmax_bdmax	0.2	0
curvelltmax_ss	0.1	1.1
carbonphytomin_ss	0.1	0.3
curvelrange_ss	0.1	0.2
carbonphytoltmax_ss	0.1	0.6
curvelmin_ss	0.1	0.7
curvelltmax_bdmax	0.0	0.4
tempmean_ss	0.0	0
templtmin_bdmean	0.0	0.1
curvelmax_ss	0.0	0
curvelltmin_bdmax	0.0	1.4
curvelltmax_bdmin	0.0	0



TEST AUC = 0.81 (trapezoidal)
Accuracy : 0.763
95% CI : (0.717, 0.805)
No Information Rate : 0.5
P-Value [Acc > NIR] : <2e-16
#
Kappa : 0.526
#
Mcnemar's Test P-Value : 0.834
#
Sensitivity : 0.771
Specificity : 0.755
Pos Pred Value : 0.759
Neg Pred Value : 0.767
Prevalence : 0.500
Detection Rate : 0.385
Detection Prevalence : 0.508
Balanced Accuracy : 0.763

Gonatus onyx

Occurrence and Encounter Probability based on abiotic and biotic factors from Bio-Oracle

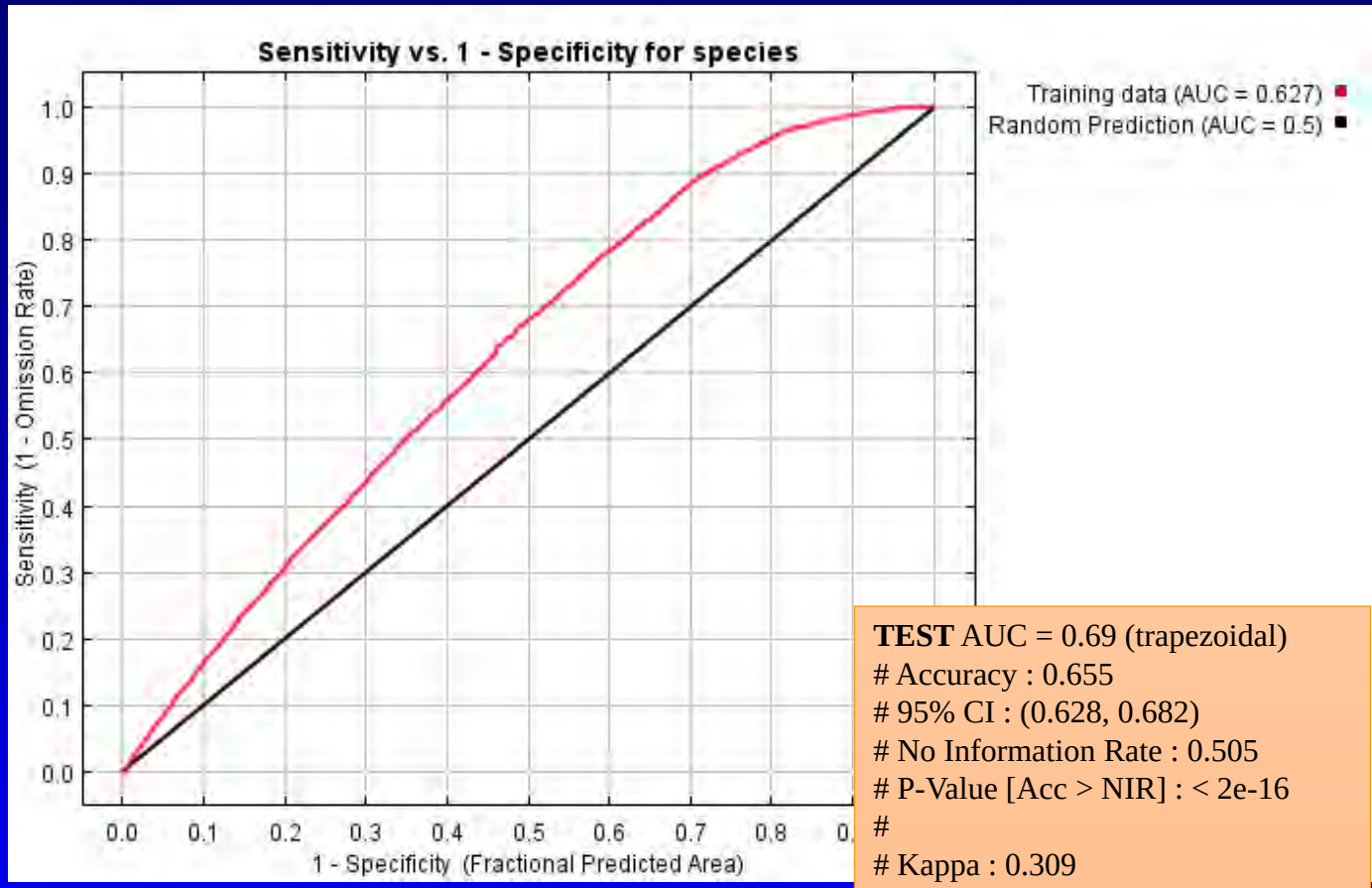


1) higher probability in the NWPO compared to NEPO

2) increased probability of occurrence along the trenches

Gonatus madokai

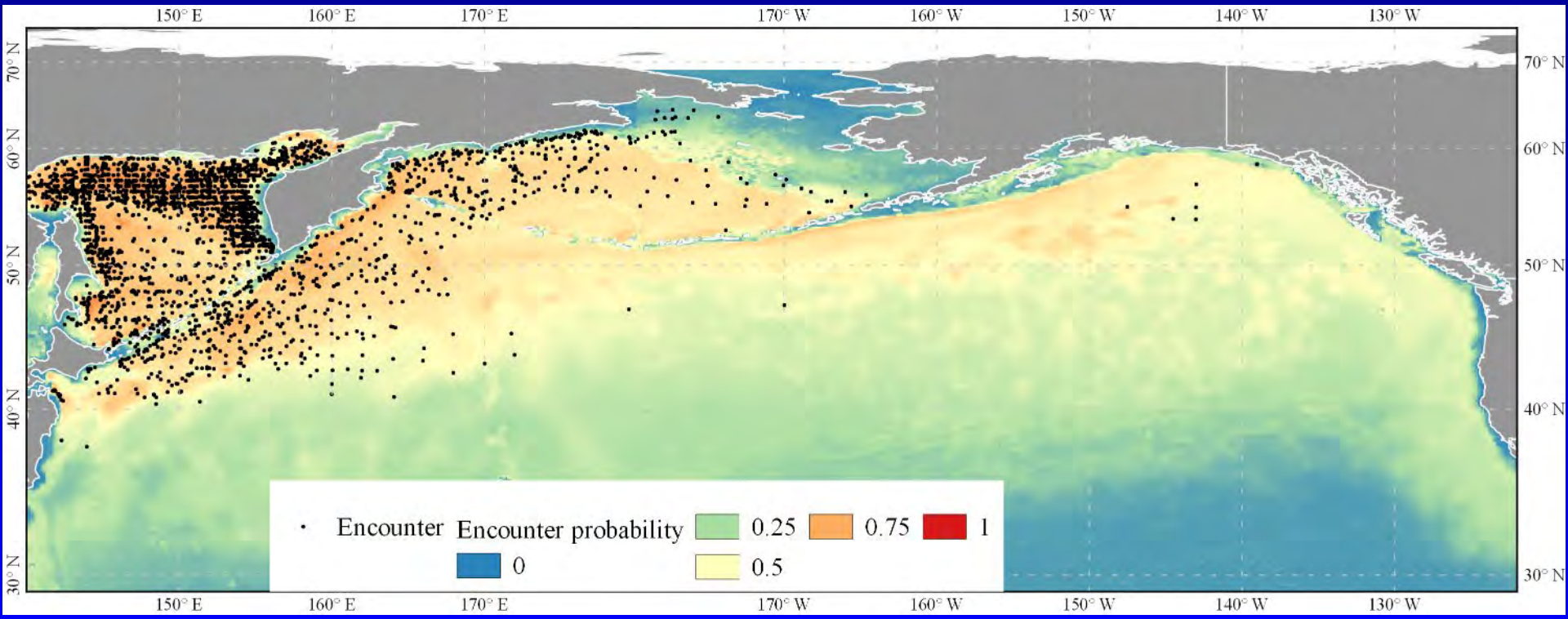
V	VI	PI
carbonphytoltmin_bdmin	42.90	7.69
carbonphytomin_ss	19.00	6.63
templtmin_ss	14.10	25.30
curvelltmin_bdmin	4.48	1.31
carbonphytoltmin_ss	2.69	6.16
curvelmin_ss	2.35	2.27
carbonphytoltmin_bdmax	2.12	2.24
curvelltmin_bdmean	1.99	0.73
carbonphytoltmax_bdmin	1.91	0.17
curvelltmax_bdmin	1.58	3.08
dissoxltmin_bdmean	1.54	0.32
templtmin_bdmin	1.51	7.14
curvelltmin_ss	0.77	2.73
templtmax_bdmin	0.67	1.84
carbonphytomean_ss	0.58	3.05
dissoxrange_ss	0.54	3.57
carbonphytomax_ss	0.30	3.43
templtmax_bdmean	0.26	8.06
bathymean	0.24	5.05
templtmin_bdmax	0.15	5.32
sstrange	0.14	2.33
templtmax_bdmax	0.08	1.04
curvelltmin_bdmax	0.07	0.35
tempmean_ss	0.07	0.20



TEST AUC = 0.69 (trapezoidal)
Accuracy : 0.655
95% CI : (0.628, 0.682)
No Information Rate : 0.505
P-Value [Acc > NIR] : < 2e-16
#
Kappa : 0.309
#
Mcnemar's Test P-Value : 1.2e-07
#
Sensitivity : 0.747
Specificity : 0.562
Pos Pred Value : 0.635
Neg Pred Value : 0.685
Prevalence : 0.505
Detection Rate : 0.377
Detection Prevalence : 0.594
Balanced Accuracy : 0.654

Gonatus madokai

Occurrence and Encounter Probability based on abiotic and biotic factors from Bio-Oracle

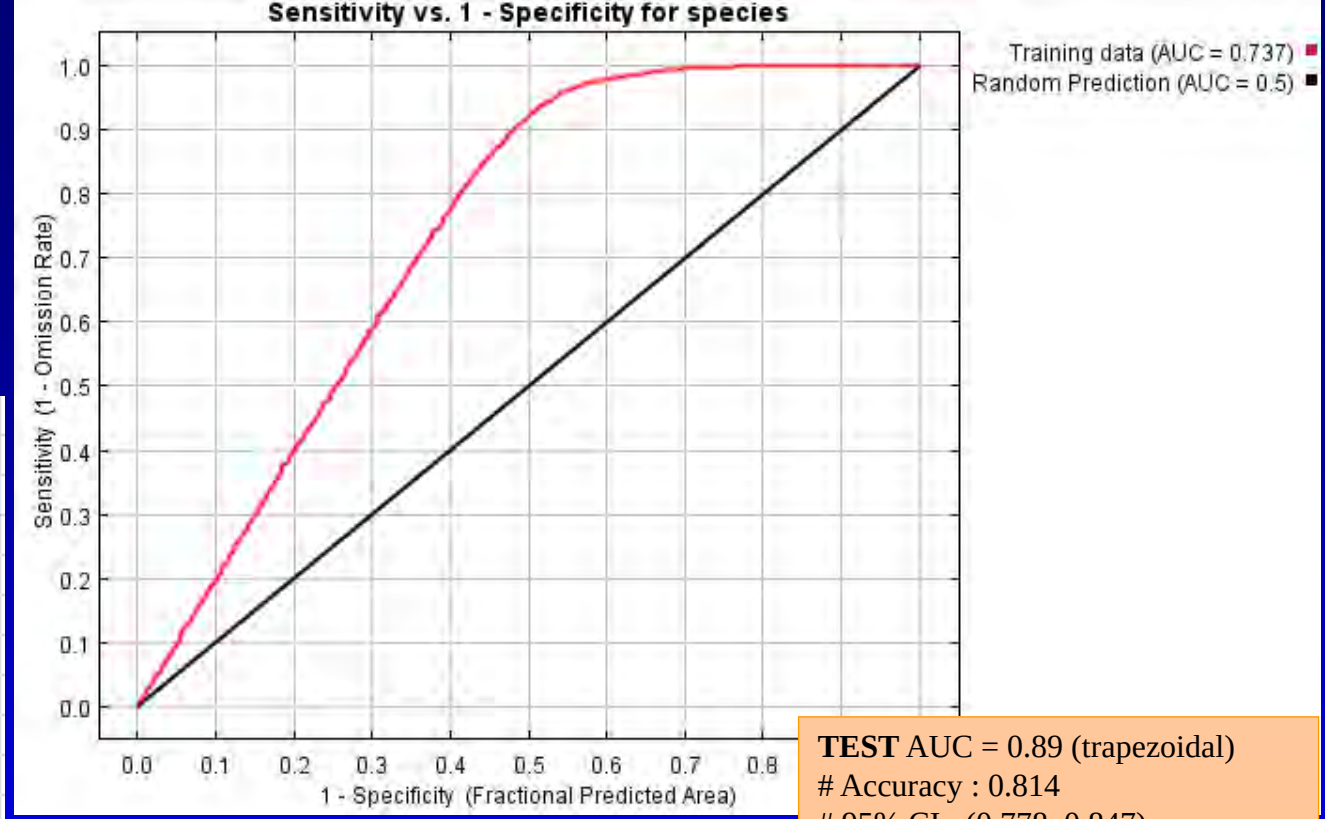


1) notably higher probability in the NWPO compared to NEPO

2) increased probability of occurrence in the Okhotsk Sea

Onychoteuthis borealijaponica

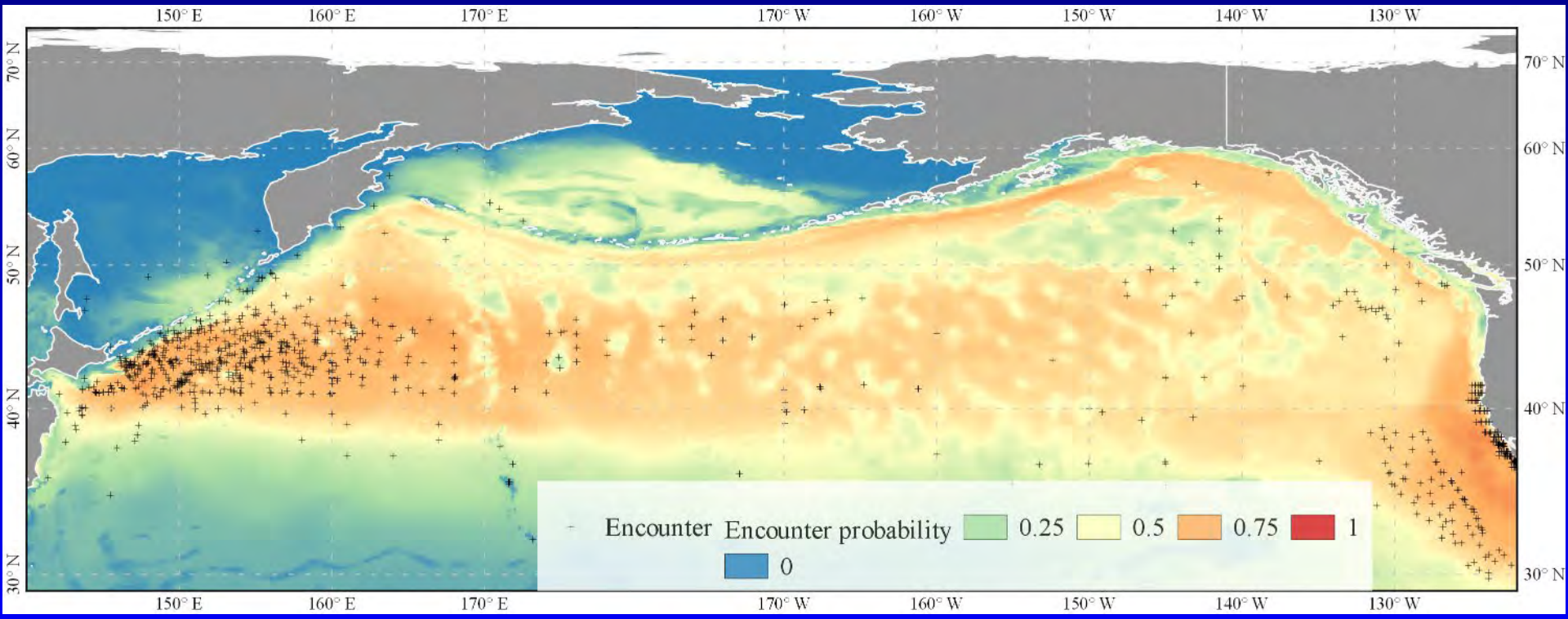
Species	borealijaponica	
V	VI	PI
templtmin_ss	73.2	50
templtmax_ss	10.4	6.4
bathymean	2.1	16.6
sstrange	2.1	1.6
curvelltmin_ss	1.7	2.3
carbonphytoltmin_ss	1.4	1.7
curvelmean_ss	1.4	1.4
dissoxrange_ss	1.3	1.4
curvelltmin_bdmean	1.1	0.4
curvelltmin_bdmax	0.9	0.1
carbonphytomax_ss	0.8	0.3
dissoxltmin_bdmean	0.8	3.6
curvelltmin_bdmin	0.7	0
dissoxltmax_ss	0.4	1.6
templtmax_bdmax	0.4	3.3
dissox	0.4	1.1
templtmax_bdmin	0.3	2.5
carbonphytomean_ss	0.3	4.8
carbonphytorange_ss	0.3	0
curvelltmax_bdmin	0.2	0
curvelmax_ss	0.1	1
dissoxltmin_ss	0.0	0
curvelrange_ss	0.0	0



TEST AUC = 0.89 (trapezoidal)
Accuracy : 0.814
95% CI : (0.778, 0.847)
No Information Rate : 0.5
P-Value [Acc > NIR] : < 2e-16
#
Kappa : 0.628
#
Mcnemar's Test P-Value : 4.59e-08
#
Sensitivity : 0.921
Specificity : 0.708
Pos Pred Value : 0.759
Neg Pred Value : 0.899
Prevalence : 0.500
Detection Rate : 0.460
Detection Prevalence : 0.607
Balanced Accuracy : 0.814

Onychoteuthis borealijaponica

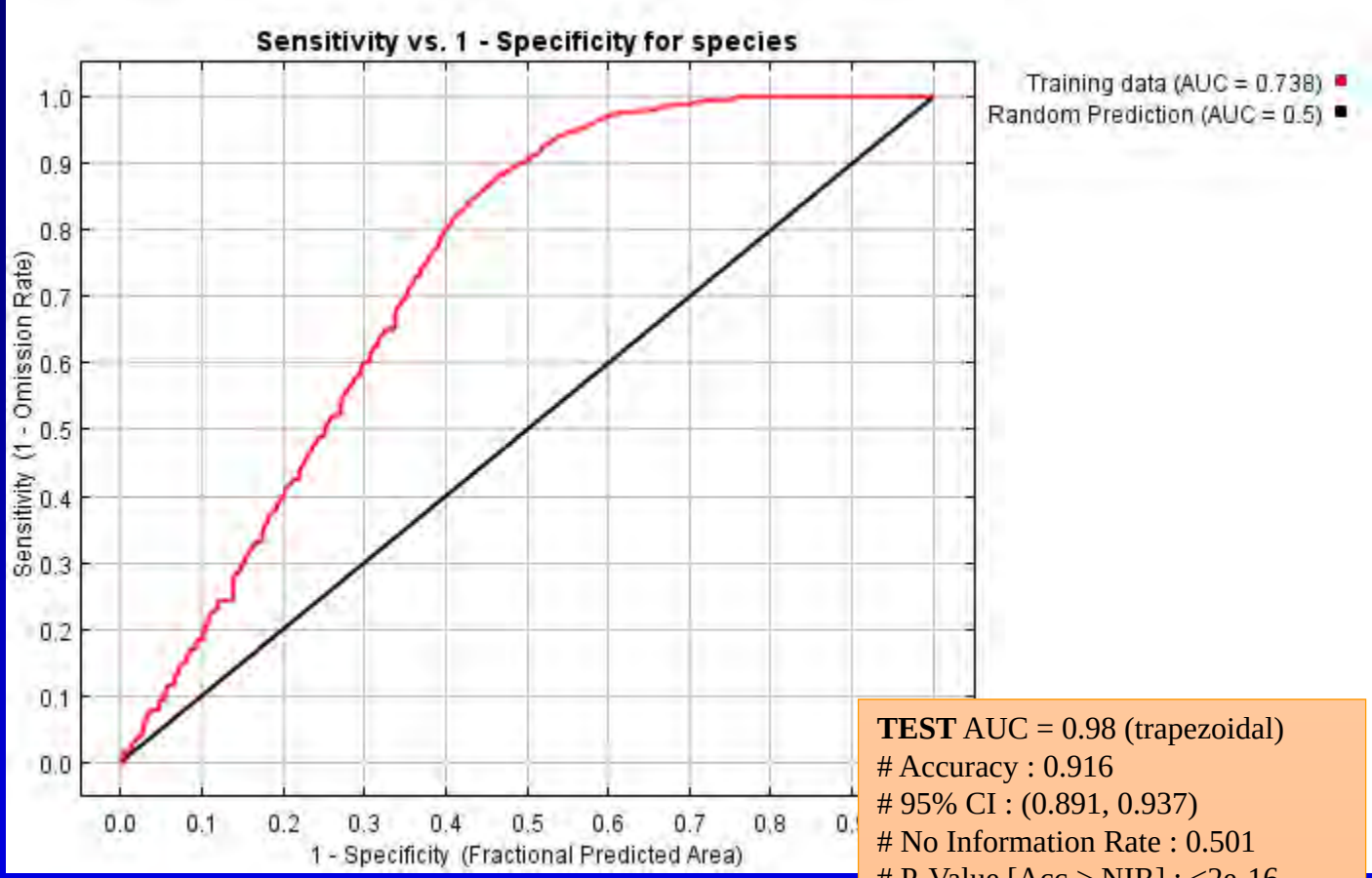
Occurrence and Encounter Probability based on abiotic and biotic factors from Bio-Oracle



1) almost 0 probability of occurrence in the upper boreal regions

2) patchy distribution in offshore areas

Abraliopsis felis

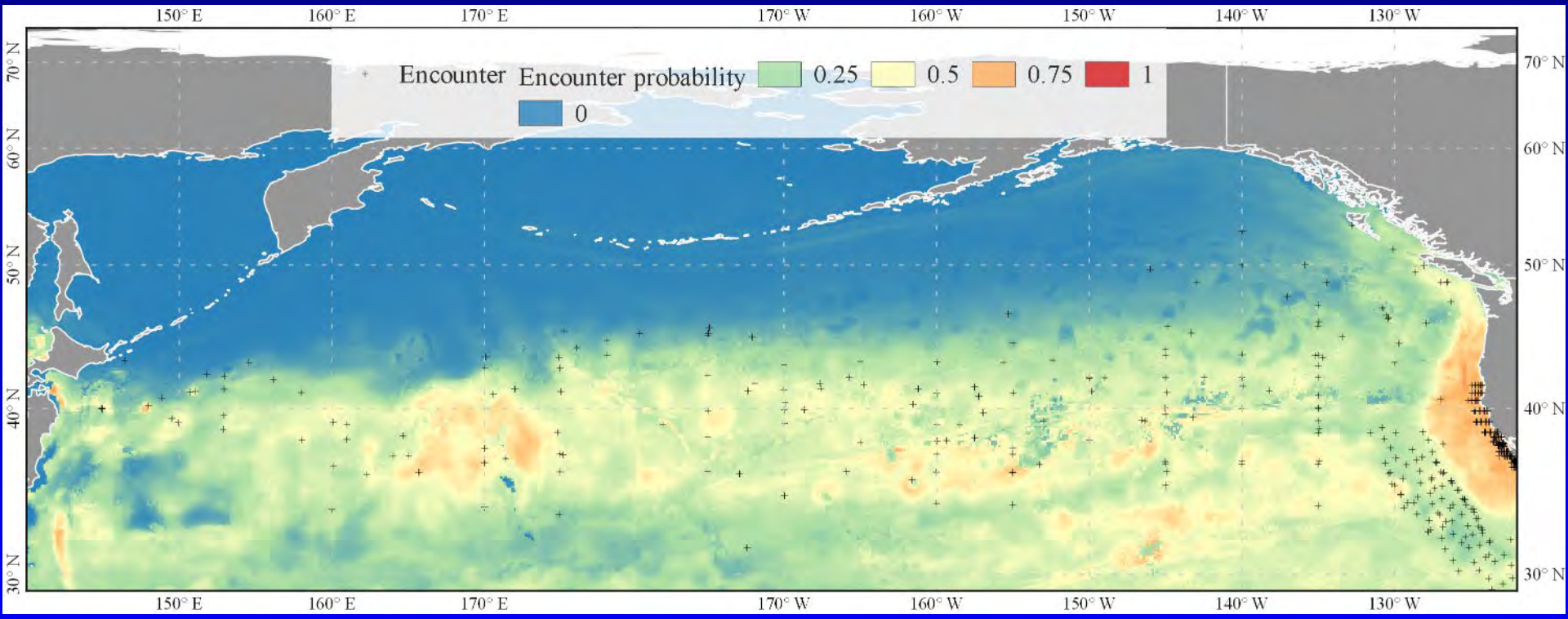


Species	felis	
V	VI	PI
templtmin_ss	29.4	51.6
carbonphytomax_ss	28.4	7.3
dissoxmean_ss	8.7	0
curvelltmax_bdmin	6.3	13.3
carbonphytoltmin_ss	5.1	8.1
curvelmean_ss	3.7	0.5
tempmean_ss	3.3	12.5
temprange_ss	2.8	0.8
sstrange	2.7	0.8
carbonphytomin_ss	2.5	2
carbonphytomean_ss	2.3	0
curvelltmin_ss	2.1	0.6
curvelmin_ss	1.4	0.4
curvelltmin_bdmax	0.6	0.6
curvelltmin_bdmin	0.4	0.7
bathymean	0.2	0.3
templtmax_ss	0.1	0.1
curvelltmax_ss	0.1	0.4

TEST AUC = 0.98 (trapezoidal)
Accuracy : 0.916
95% CI : (0.891, 0.937)
No Information Rate : 0.501
P-Value [Acc > NIR] : <2e-16
#
Kappa : 0.831
#
Mcnemar's Test P-Value : 0.401
#
Sensitivity : 0.904
Specificity : 0.927
Pos Pred Value : 0.925
Neg Pred Value : 0.906
Prevalence : 0.499
Detection Rate : 0.451
Detection Prevalence : 0.488
Balanced Accuracy : 0.916

Abraliopsis felis

Occurrence and Encounter Probability based on abiotic and biotic factors from Bio-Oracle



1) higher probability of occurrence in the subtropical belt

2) patchy (uneven) pattern

General observations on potential distribution patterns in the NPO for pelagic squid that have been encountered in the GoA 2019 spring survey

- **specific habitat suitability patterns were constructed using MaxEnt for pelagic squid based on known species long-term occurrence in the NPO (TINRO database and GBIF) and Bio-Oracle layers**
- **from 17 to 30 abiotic and biotic variables per species were selected using PI (permutaion importance) and VC (variable contribution) to produce statistically robust (with AUC>0.65) distribution profiles for 6 species of pelagic squid**

- **the constructed potential distribution maps suggested that 4 species of the family Gonatidae (*Okutania anonycha, Boreoteuthis borealis, Gonatus onyx* and *G.madokai*) were associated basically with high latitude boreal (cold water) areas in the NPO, whereas the Enoploteuthid species (*Abraliopsis felis*) was associated mainly with lower latitude subtropical areas, and the Onychoteuthid species (*Onychoteuthis borealijaponica*) showed wide occurrence from subtropical through transitional and up to boreal waters**

- **specific spatial distribution differences were revealed for the Gonatid squid:**

(1) *Okutania anonycha, Boreoteuthis borealis* and *Gonatus onyx* showed up as wide-boreal trans-pacific species, whereas *Gonatus madokai* showed clear tendency to be distributed mainly in the northwestern NPO

(2) *Okutania anonycha* habitat appeared as mainly broadly oceanic offshore, whereas that of *Boreoteuthis borealis* more associated with higher latitude areas, and *Gonatus onyx* tended to be related to deep-sea trenches

How does the information collected in the GoA 2019 cruise reflect the known (database) and revealed (modeled) patterns of distribution of pelagic squid?

- 5 out of 6 species that have been encountered in the GoA 2019 cruise well fit into the known and modeled distribution patterns:

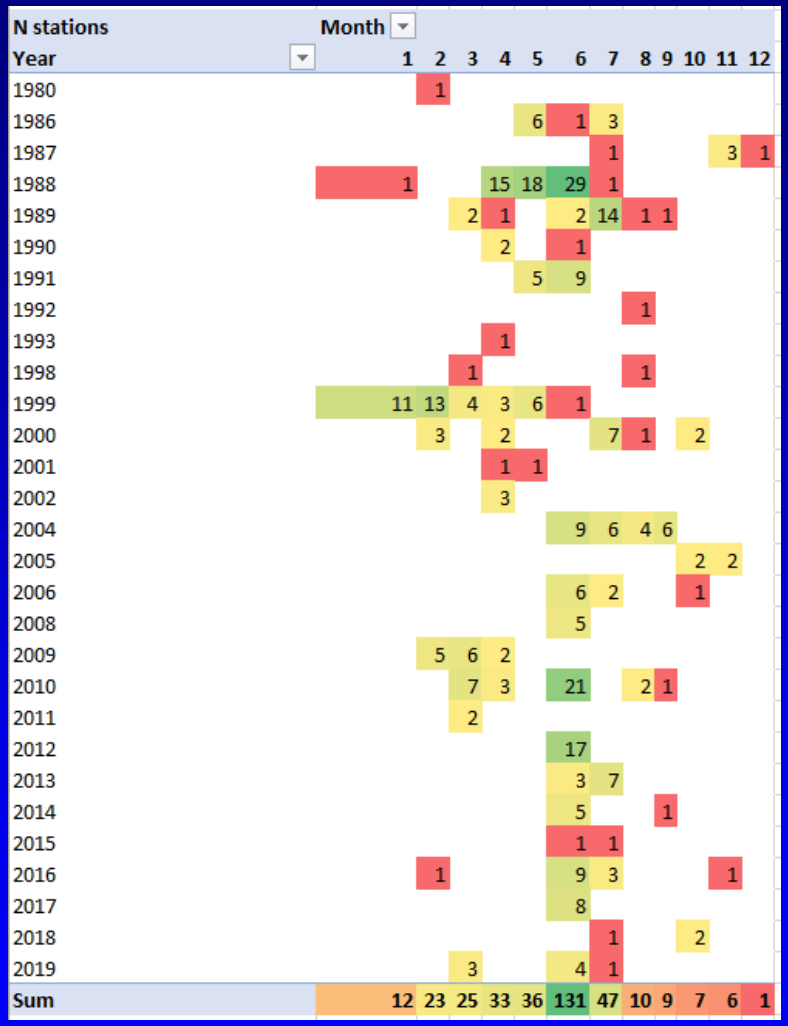
- ***Boreoteuthis borealis*** and ***Onychoteuthis borealijaponica*** appeared as common species in the research area, **GoA observations on those species well fit their known and potential distribution patterns**;
- ***Gonatus onyx*** and ***G. madokai*** were much less frequently occurring than the first two, which **was less expected for *G.onyx*, than for *G.madokai***;
- ***Abraliopsis felis*** were observed mainly to the south-west of the research area, which was also **in line with the species distribution patterns**

- **ONE** species, the smallfin gonate squid ***Okutania anonycha*** (=***Berryteuthis anonychus***), which was supposed to be highly abundant in the research area, occurred only in fish stomachs in the GoA 2019 spring survey **!!! Several reasons for that can be considered…**

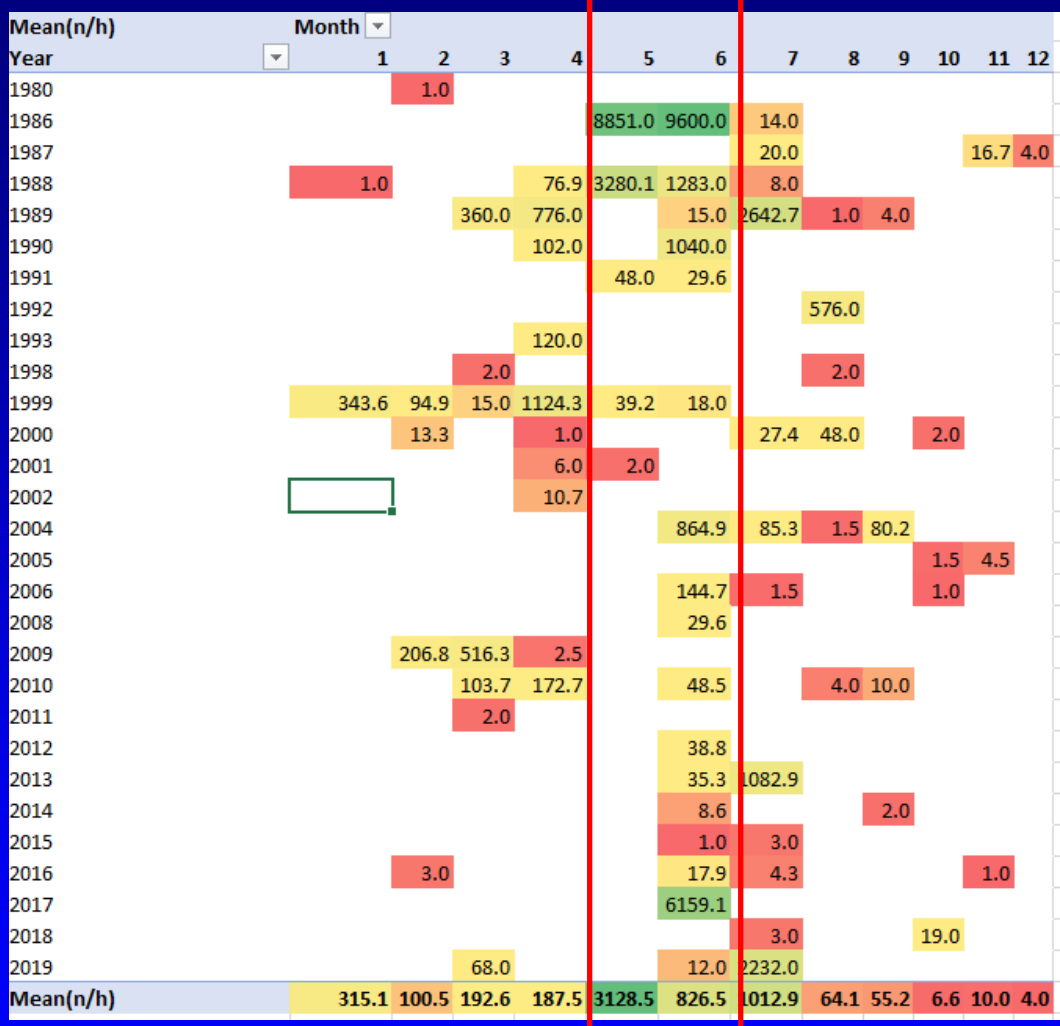
Possible reasons for the absence of *Okutania anonycha* in the upper-epipelagic trawl catches in GoA in 2019 early spring survey

- False negative occurrence due to **wrong season** for research
- False negative occurrence due to **wrong water layer** studied (too shallow)

Season



N stations	Month											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1980		1										
1986					6	1	3					
1987							1				3	1
1988	1			15	18	29	1					
1989			2	1		2	14	1	1			
1990				2		1						
1991					5	9						
1992								1				
1993				1								
1998			1					1				
1999	11	13	4	3	6	1						
2000		3		2			7	1		2		
2001				1	1							
2002				3								
2004						9	6	4	6			
2005										2	2	
2006						6	2			1		
2008						5						
2009		5	6	2								
2010			7	3		21		2	1			
2011			2									
2012						17						
2013						3	7					
2014						5			1			
2015						1	1					
2016		1				9	3				1	
2017						8						
2018							1			2		
2019			3			4	1					
Sum	12	23	25	33	36	131	47	10	9	7	6	1



Mean(n/h)	Month											
Year	1	2	3	4	5	6	7	8	9	10	11	12
1980		1.0										
1986					8851.0	9600.0	14.0					
1987							20.0				16.7	4.0
1988	1.0			76.9	3280.1	1283.0	8.0					
1989			360.0	776.0		15.0	2642.7	1.0	4.0			
1990				102.0		1040.0						
1991					48.0	29.6						
1992								576.0				
1993				120.0								
1998			2.0					2.0				
1999	343.6	94.9	15.0	1124.3	39.2	18.0						
2000		13.3		1.0			27.4	48.0		2.0		
2001				6.0	2.0							
2002				10.7								
2004						864.9	85.3	1.5	80.2			
2005										1.5	4.5	
2006						144.7	1.5			1.0		
2008						29.6						
2009		206.8	516.3	2.5								
2010			103.7	172.7		48.5		4.0	10.0			
2011			2.0									
2012						38.8						
2013						35.3	1082.9					
2014						8.6			2.0			
2015						1.0	3.0					
2016		3.0				17.9	4.3				1.0	
2017						6159.1						
2018							3.0			19.0		
2019			68.0			12.0	2232.0					
Mean(n/h)	315.1	100.5	192.6	187.5	3128.5	826.5	1012.9	64.1	55.2	6.6	10.0	4.0

- **all-year-round occurrence**
- **maximum occurrence – April-July**
- **peak density in May-June**

Depth

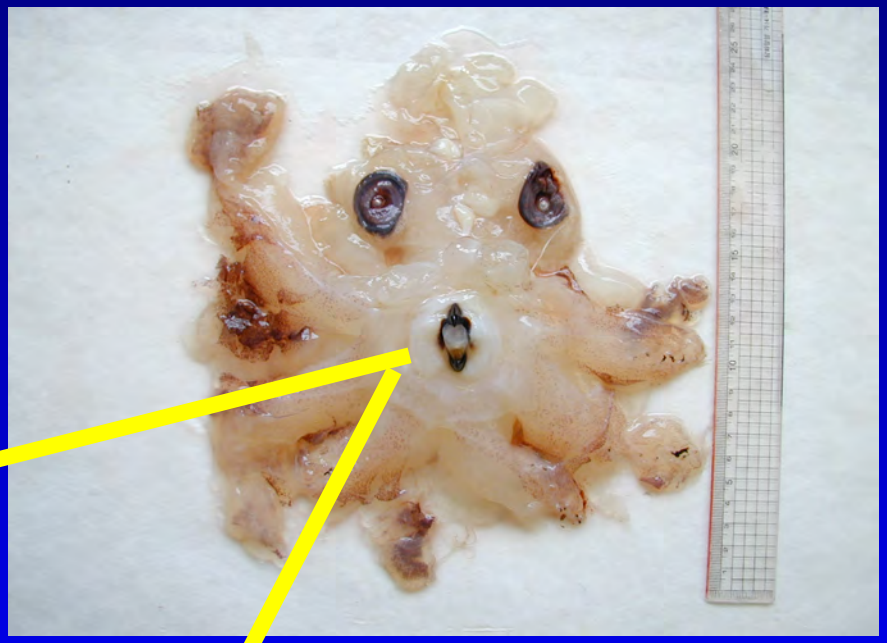
n > 0			
Depth of trawl	n/h	kg/h	n stations
000-050	829		217
051-100	2682		31
101-200	468		27
201-300	30		16
301-400	58		22
401-500	454		15
501-600	400		1
601-700	2		1
701-800	15		7
			337

n > 0 AND kg > 0	n/h	kg/h	n stations
000-050	843	31.355	213
051-100	2865	37.537	29
101-200	524	7.485	24
201-300	29	0.613	15
301-400	58	2.783	22
401-500	518	8.034	13
501-600	400	34.180	1
601-700	2	0.012	1
			318

- **uneven depth occurrence**
- **maximum density at 50-100 m**
- **second peak at 400-600 m**

Cephalopods

- Love them
- Catch them
- Eat them
- Study them – they are key components in pelagic marine ecosystems!!!



Thank you!