Oxygen decline in the continental slope waters off-Japan and its potential influence on groundfishes

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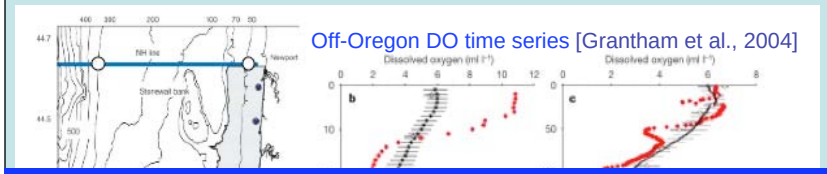
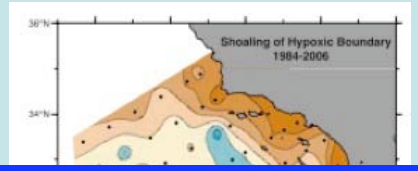
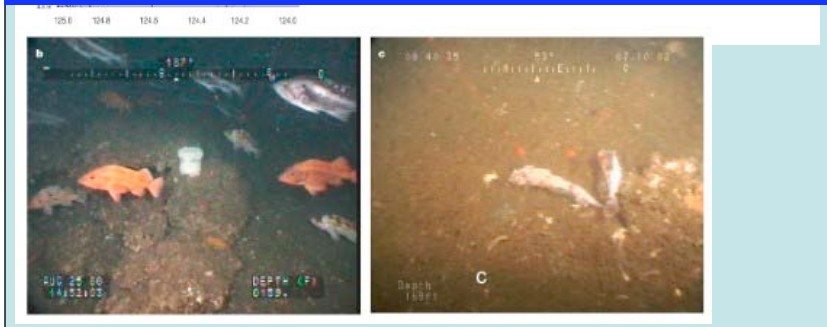


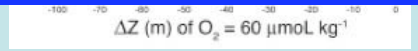
Off-Oregon DO time series [Grantham et al., 2004]



Research Objective:

What are the situation of hypoxia in the west coast NP?





CalCOFI hypoxic boundary
[Bograd et al., 2008]

Critical DO level for various marine organisms

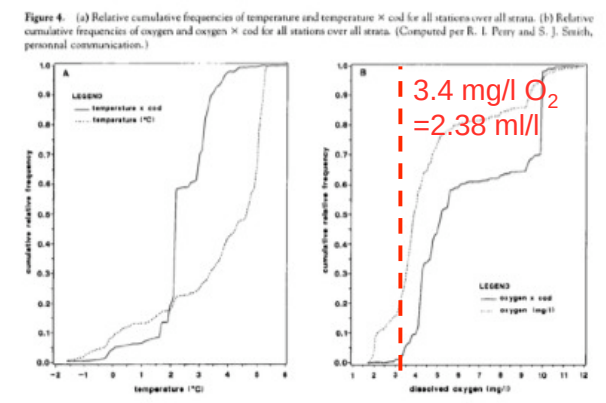
experimentaly obtained "hypoxia criteria" for various marine organisms

[after *Vaquer-Sunyer & Duarte, 2008*]

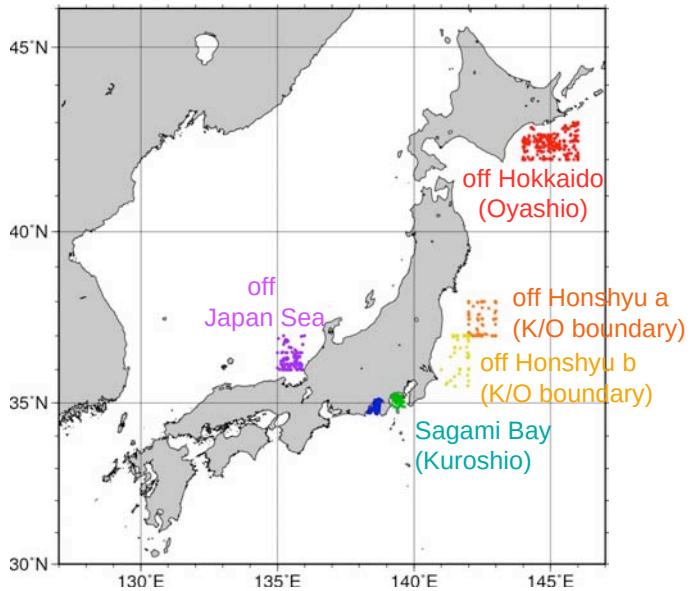
Organisms	n	LC50 [ml/l]	escape limit [ml/l]	LT50 [hour]
Fish	77	1.08 ±0.05	<1.4	60
Crustaceans	168	1.7±0.1		56
Gastropodas	12	0.62±0.08		
Bivalves	19	1.0±0.1		

Tentative criteria of "hypoxia" in western NP : 1.4 ml/l (=60 µmol/kg)

Habitat limitation by oxygen
for Atlantic cod in Gulf of St. Laurence
[D'Amours, 1993]



data analyzed : DO



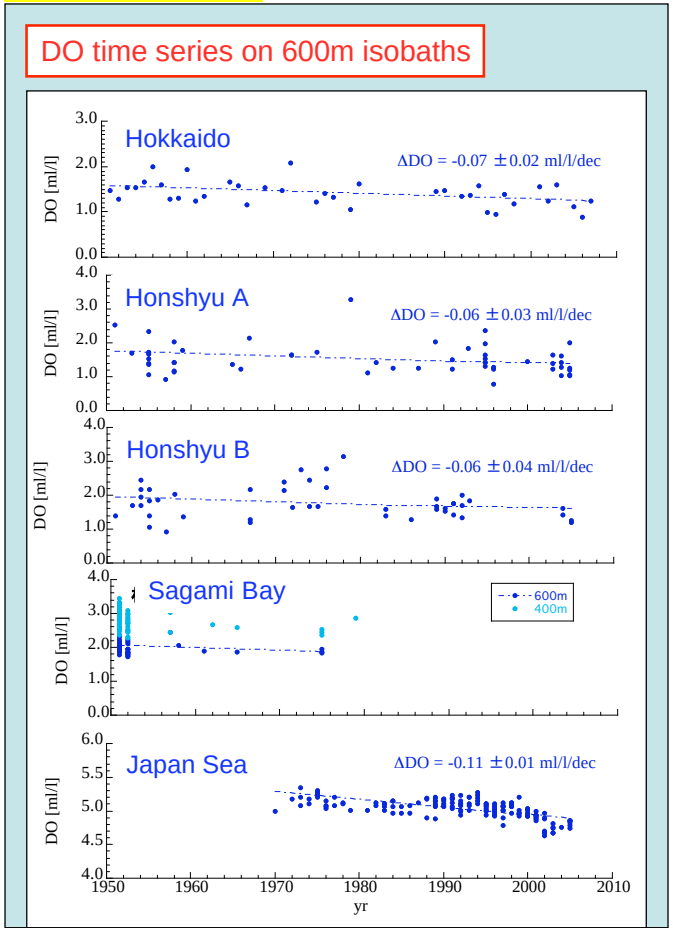
- 1308 data of JODC for:
  - *continental slope area
  - *over 30y time length within small rectangle

- DO data are interporated to :
  - *isobath: 200m,300m,400m,500m, 600m,800m,1000m,
  - *isopycnal: corresponding to above isobath surface at present

Area	Longitude x Latitude	Time rength	data No.
off Hokkaido	144E-146E、North of 42N	1951-2005	404
off Honshyu A	west of 143E, 37N-38N	1951-2005	117
off Honshyu B	west of 142, 35.5N-37N	1951-2005	61
Sagami Bay	insyde of the Bay	1951-1980	146
off Japan Sea	135E-136E、south of 37N	1954-2005	580

Results : overall

DO time series on 600m isobaths



- Negative DO trend with statistical significance of $\alpha<0.05$ for all area except Sagami Bay (Kuroshio region)

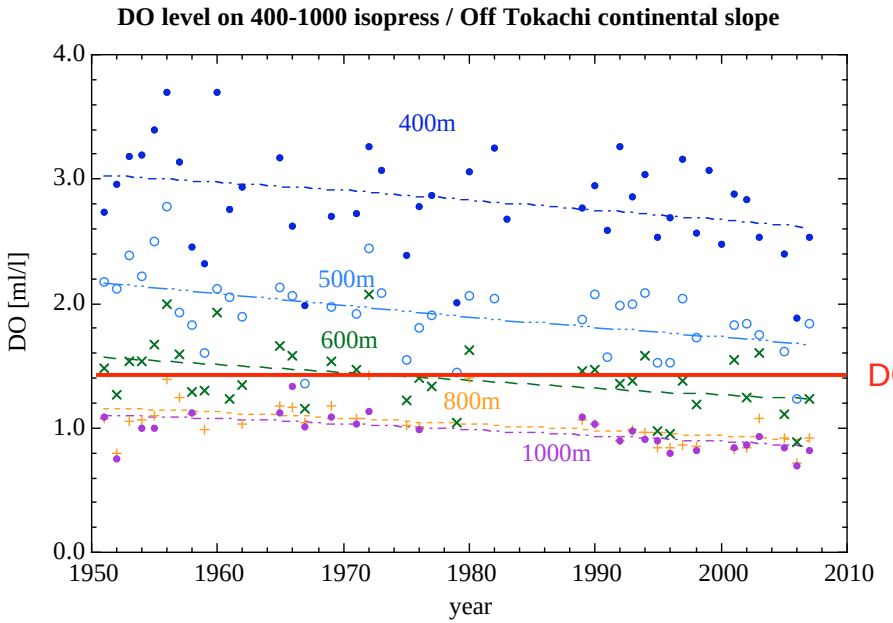
- DO decreasing rate: max in Japan Sea (-0.11ml/l/dec)

  *but DO level is still high in Japan Sea continental slope.

- off Hokkaido / Honshyu continental slopes seems in critical phase

(decreasing rate -0.06 ~ -0.07 ml/l/dec)
(DO level <1.5 ml/l at present 600m)

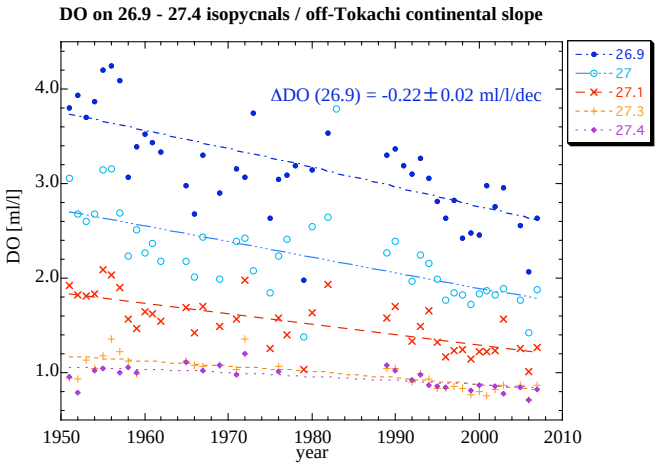
detailed DO time series off Hokkaido continental slope

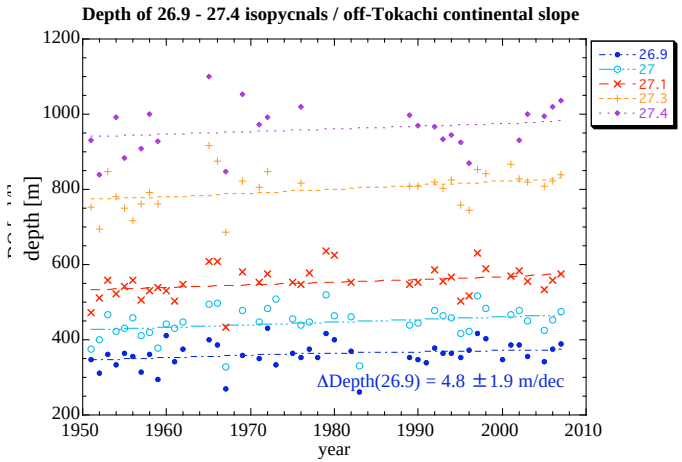


DO =1.4 ml/l

・statistically significant DO decrease on all isobaths from 400m to 1000m (rate : - 0.04 ~ -0.09 ml/l/decade)

・hypoxia boundary（DO = 1.4ml/l）: ascending from 680m（1951）to 560m（2010）（rate : ~20m/dec)



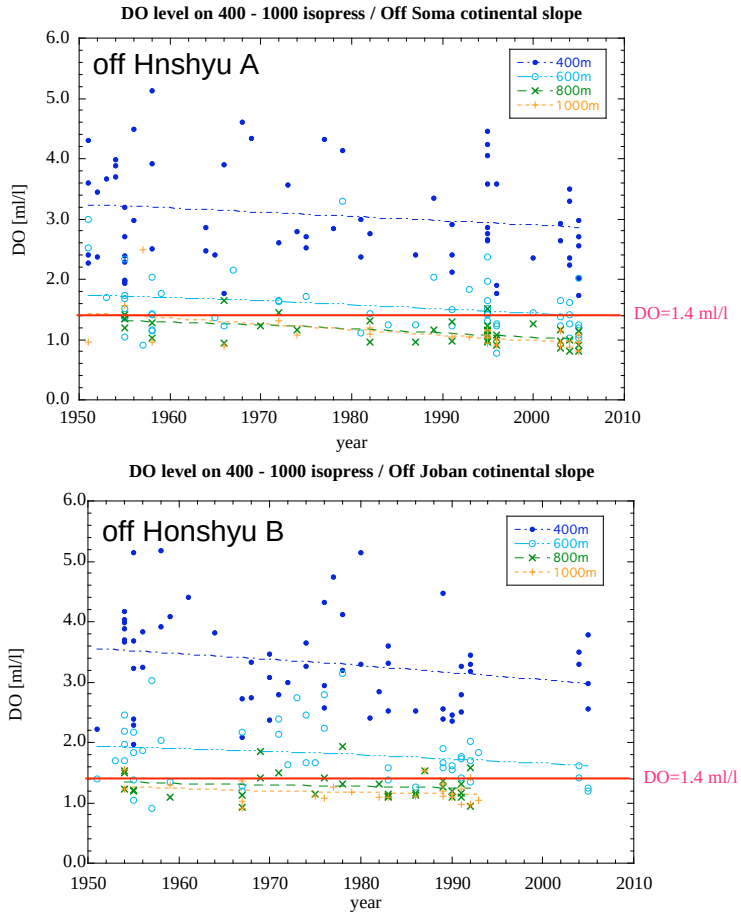


DO decrease on isopycnals
(26.9 ~ 27.4)
on off-Hokkaido continental slopes

*DO decreasing rate on isopycnals is in fact, far larger than those on isobath (ca. -0.2 ml/dec)

=>such large trend has compensated by small descending trend of isopycnal surface in off-Hokkaido area.

detailed DO time series off Honshyu continental slope

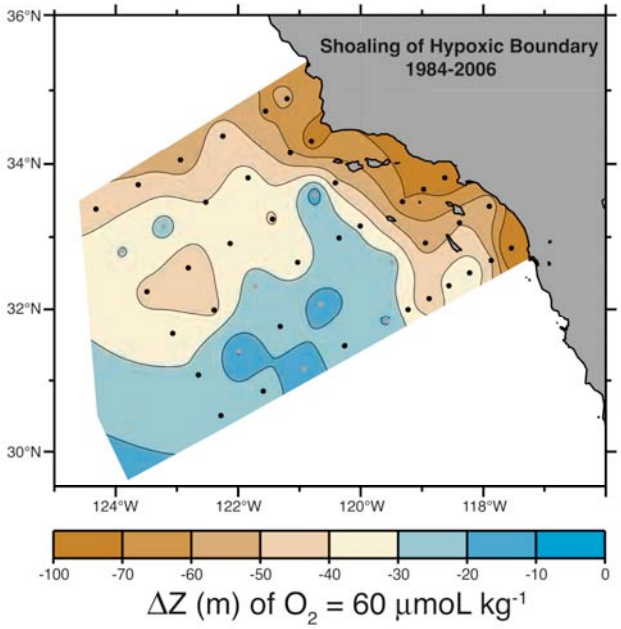


- singinificant negative DO trend obtained at both Honshyu A (400m-1000m) and Honshyu B (400-600m)

Hypoxic boundary in Honshyu A:
800m(1951) =>590m(2010)
ascending at 35m/dec

Hypoxic boundary in Honshyu B:
800m(1951) =>700m(2010)
ascending at 17m/dec

Ascending rate of CalCOFI hypoxic boundary
[Bograd et al., 2008]

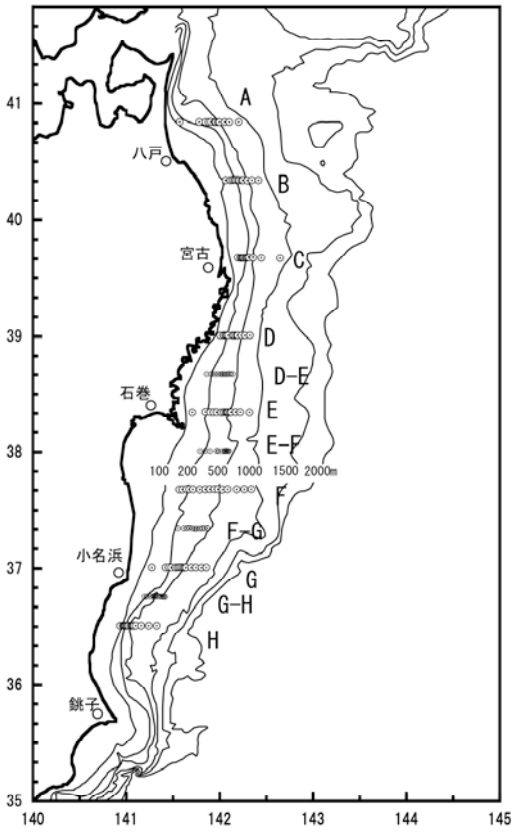


CA. -20 ~ -40 m/dec at off California coast

Observed Ascending rate
at off-Japan continental slopes
(-20 ~ -35 m/dec)
resembles to those observed at
off California coast.

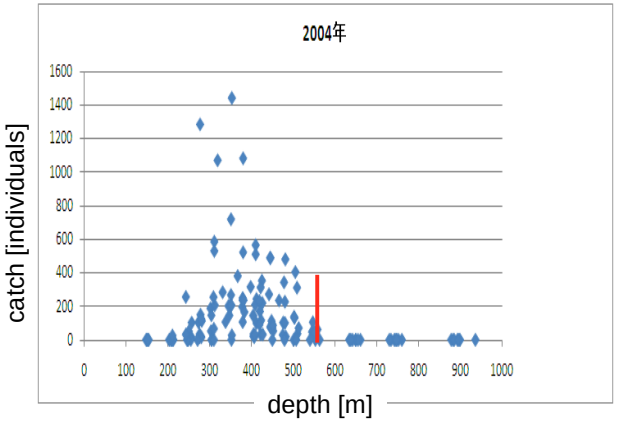
off-Japan hypoxic disease is
still invisible, but ongoing steady!

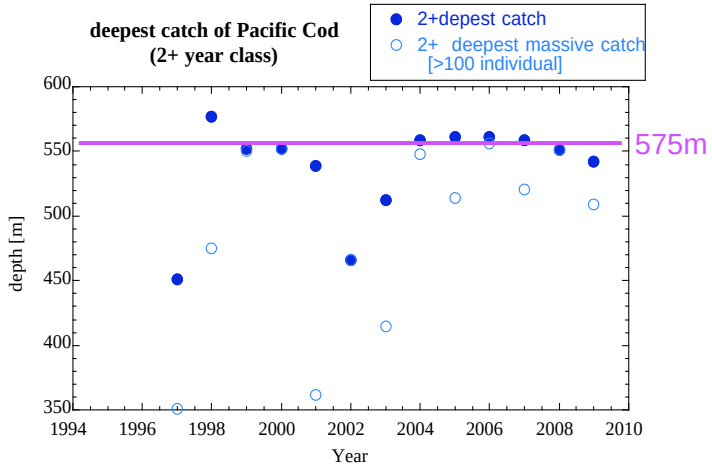
effect on groundfishes: present distribution of off-Honshyu ground fishes with respect to oxygen

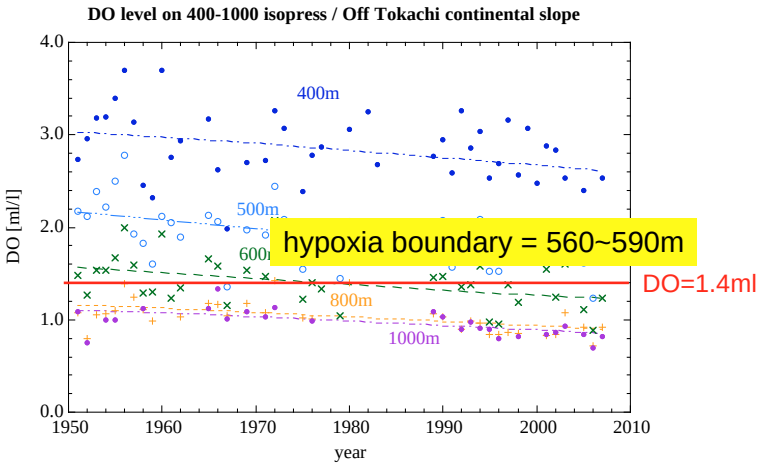


off-Tohoku ground trawl net data
from 1997 to 2009

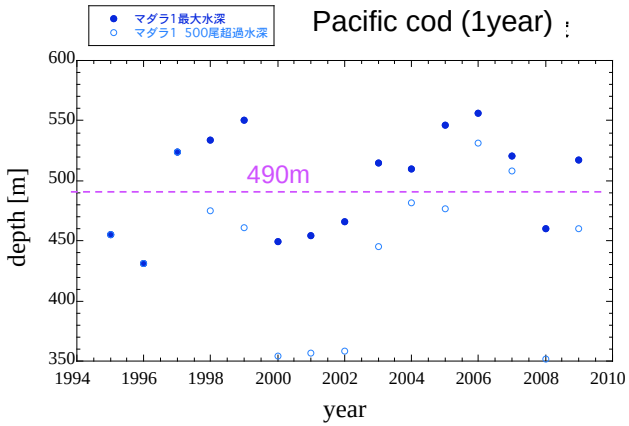
*deepest catch of Pacific Cod (*Gadus macrocephalus*) in each year is extracted

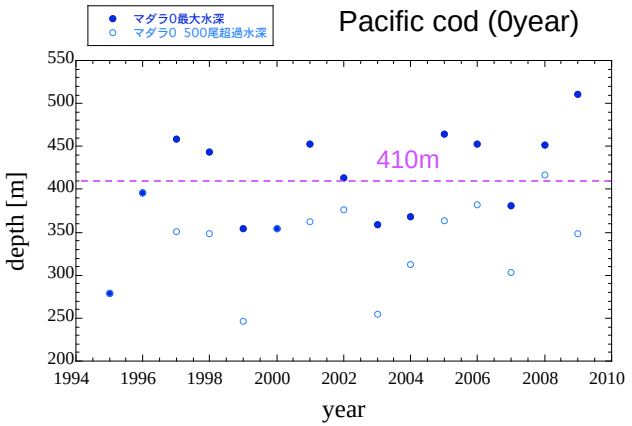






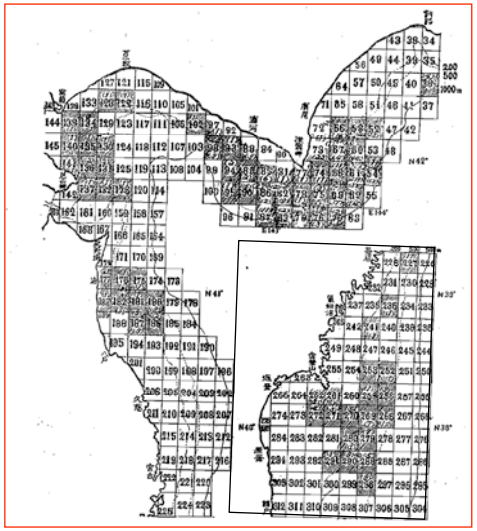
present lower limit of Pacific Cod (2+) catch agrees well to DO=1.4 ml/l hypoxia boundary


マダラ1最大水深
マダラ1　500尾超過水深
Pacific cod (1year)
490m
depth [m]
year
600
550
500
450
400
350
1994
1996
1998
2000
2002
2004
2006
2008
2010


マダラ0最大水深
マダラ0　500尾超過水深
Pacific cod (0year)
410m
depth [m]
year
550
500
450
400
350
300
250
200
1994
1996
1998
2000
2002
2004
2006
2008
2010

Temporal change of Pacific cod habitat depth: a tentative result

・depth-sensitive ground trawl (Seine net) data in 1957 at off-Hokkaido and Honshyu continental slopes



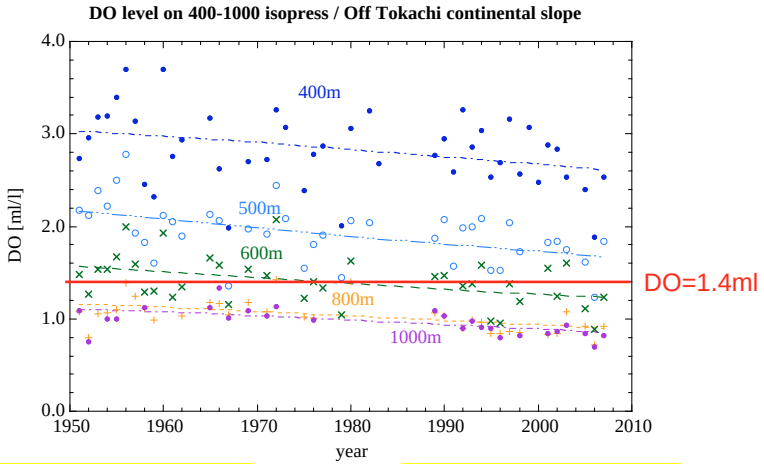
depth[m]

catch of Pacific cod [10kann; =37.5kg]

別 表 1 (a) 標準 続き

調査年月日	漁船	区名	水深m ＼ 魚種	アブラガレイ	サメガレイ	ババガレイ	ヒレグロ	その他のカレイ	マダラ	スケトウダラ	キチジ
7. 23	61	C	630 ～ 670	14.0	161.0	—	—	—	—	—	3.0
〃	〃	〃	625 ～ 650	12.0	189.0	—	—	—	—	—	1.2
* 〃	〃	〃	620 ～ 695	20.0	130.0	—	—	—	—	—	2.0
24	〃	〃	620 ～ 680	24.0	192.0	—	—	—	—	—	5.0
〃	〃	〃	625 ～ 700	28.0	175.0	—	—	—	—	—	8.0
〃	〃	〃	630 ～ 660	28.0	259.0	—	—	—	—	—	6.0
〃	〃	〃	630 ～ 670	28.0	224.0	—	—	—	—	—	1.5
25	〃	〃	650 ～ 660	8.0	141.0	—	—	—	—	—	1.8
〃	〃	〃	650 ～ 670	14.0	102.0	—	—	—	—	—	6.0
〃	〃	〃	600 ～ 650	28.0	100.0	—	—	—	—	—	6.0
〃	〃	〃	630 ～ 690	4.0	187.0	—	—	—	—	—	3.0
26	〃	〃	620 ～ 660	21.0	170.0	—	—	—	—	—	1.0
〃	〃	〃	620 ～ 680	10.0	80.0	—	—	—	—	—	5.5
* 27	〃	〃	660 ～ 680	35.0	132.0	—	—	—	—	—	5.0
〃	〃	〃	725 ～ 650	14.0	100.0	—	—	—	—	—	0.4
28	〃	〃	685 ～ 710	10.0	110.0	—	—	—	—	—	0.4
30	〃	〃	580	5.0	4.0	—	—	—	—	—	—
〃	〃	〃	600	4.0	2.0	—	—	—	—	—	—
7. 17	61～62	C	600 ～ 660	20.0	45.0	—	—	—	—	—	4.0
〃	〃	〃	600 ～ 660	25.0	55.0	—	—	—	—	—	2.0
* 〃	〃	〃	600 ～ 670	20.0	40.0	—	—	—	—	—	1.5
18	〃	〃	600 ～ 670	15.0	25.0	—	—	—	—	—	1.5
* 〃	〃	〃	640 ～ 670	30.0	55.0	—	—	—	—	—	3.0
7. 7	62	B	600	1.0	6.0	2.0	4.0	6.0	1.0	2.0	6.0
〃	〃	〃	600	0.2	10.0	3.0	1.0	1.0	1.0	1.0	0.2
〃	〃	〃	580 ～ 600	0.1	7.0	5.0	2.0	2.0	0.2	0.5	0.4
〃	〃	〃	600 ～ 585	0.5	8.0	12.0	4.0	4.0	0.5	0.5	0.3
7. 3	68	C	150	25.0	20.0	21.0	—	8.0	—	6.0	13.0
〃	〃	〃	150	28.0	25.0	20.0	—	14.0	—	3.0	18.0
〃	〃	〃	145	15.0	14.0	35.0	—	6.0	—	6.5	30.0
* 4	〃	〃	150	35.0	45.0	42.0	0.2	14.0	0.5	4.0	24.0
〃	〃	〃	148	28.0	21.0	21.0	—	14.0	0.4	6.0	18.0
* 7	〃	〃	145	61.0	50.0	42.0	—	0.6	—	1.0	20.0
〃	〃	〃	140	43.0	47.0	45.0	6.0	0.2	1.0	3.0	15.0
〃	〃	〃	135	22.0	25.0	40.0	15.0	2.0	0.8	2.0	20.0
7. 4	68～69	C	140	35.0	28.0	40.0	—	—	2.0	6.0	12.0
* 5	〃	〃	145	20.0	33.0	18.0	—	7.0	—	6.0	6.0
〃	〃	〃	150	14.0	7.0	21.0	—	0.5	—	6.5	18.0
* 〃	〃	〃	155	28.0	30.0	19.0	—	15.0	—	18.0	25.0
6	〃	〃	150	20.0	19.0	21.0	—	0.5	—	12.0	4.0
〃	〃	〃	150	33.0	22.0	21.0	0.3	—	0.3	7.0	7.5
〃	〃	〃	145	21.0	65.0	28.0	—	5	0.5	8.5	10.0
7. 8	76	B	700	10.0	12.0	8.0	0.1	4.0	1.0	3.0	—
〃	〃	〃	700	11.0	14.0	7.0	0.4	3.0	2.0	3.0	—
* 〃	〃	〃	690 ～ 750	54.0	42.0	36.0	0.3	0.0	4.0	7.0	—
〃	〃	〃	685 ～ 730	36.0	30.0	24.0	0.5	5.0	2.0	6.0	—
* 7. 9	79	B	720 ～ 685	35.0	16.0	20.0	0.3	6.0	1.5	3.0	—
〃	〃	〃	700 ～ 690	15.0	24.0	18.0	0.5	5.0	2.5	2.0	—
* 〃	〃	〃	680 ～ 710	17.0	24.0	12.0	0.2	2.0	1.0	1.0	—
〃	〃	〃	720	30.0	18.0	20.0	0.4	6.0	2.0	1.0	—
* 7. 6	85	B	230 ～ 190	0.5	6.0	2.0	1.0	0.2	1.0	1.0	8.0
〃	〃	〃	260	0.4	7.0	1.0	2.0	0.5	1.0	2.0	6.0
7. 1	89	B	200 ～ 230	—	4.0	1.0	—	0.3	—	2.0	6.0
* 〃	〃	〃	240 ～ 210	—	5.0	—	1.0	0.2	—	3.0	13.0
〃	〃	〃	230 ～ 250	—	3.0	0.4	1.0	—	—	6.0	12.0
* 〃	〃	〃	250 ～ 230	—	6.0	—	0.2	—	—	10.0	18.0

Catch of Pacific cod at over 700m depth has recorded in several stations in 1957 ground trawl data



hypoxia boundary:
680~800m(1951)

hypoxia boundary:
560~590m(present)

deepest catch of Pacific cod:
at least >700m
(1957)

deepest catch of Pacific cod:
around 575m
(present)

Habitat depth of Pacific cod in off-Hokkaido/off-Honshyu continental slopes are likely to be ascending in parallel with ascending of Hypoxic boundary.

Conclusion: Oxygen decline in the continental slope waters off-Japan and its potential influence on groundfishes

- It is certain that oxygen content on off-Japan continental slopes are decreasing, and as this result, hypoxia boundary (DO = 1.4 ml/l) has been ascending as same rate as that of NP eastern coasts, ca. 20~35 m/decade.

- Influence of Hypoxia has not been visible in western NP continental shelf because hypoxia boundary lies still over 550m depth.

- However, it is likely that ascending hypoxia boundary had already exerted some influence onto continental slope ecosystems in western NP.
  In particular, it is quite likely that off-Hokkaido/Honshyu population of Pacific cod had diminished their habitat depth from over 700m to ~575m during the recent 60 years due to the ascending of hypoxia boundary.