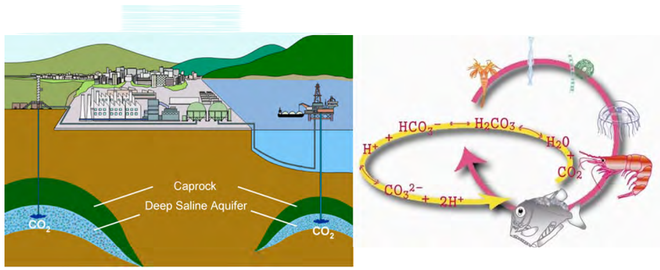
19th – 20th January, 2017

THE SASAKAWA PEACE FOUNDATION OPRI THE OCEAN POLICY RESEARCH INSTITUTE

Mitigation option - CCS and the Marine Environment



Jun Kita

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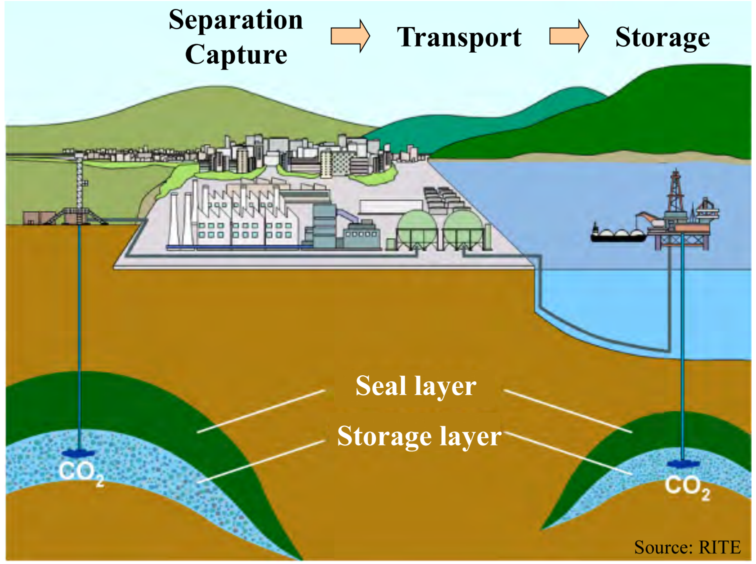
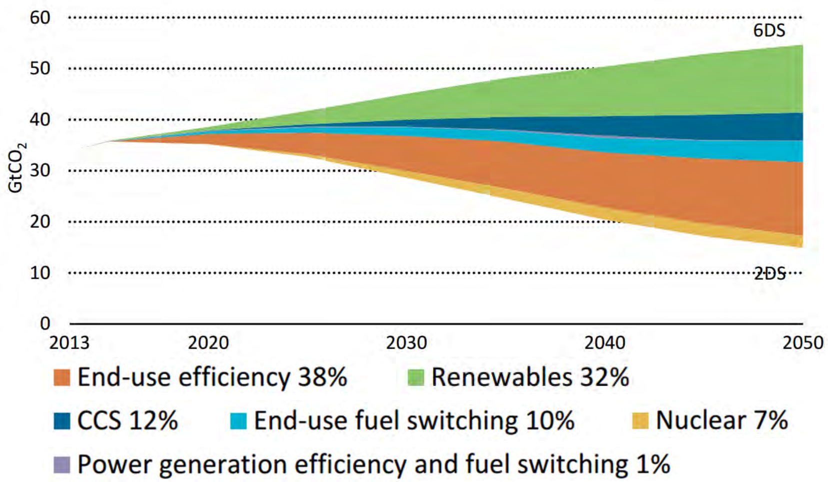
MARINE ECOLOGY RESEARCH INSTITUTE

Carbon dioxide Capture and Storage (CCS)

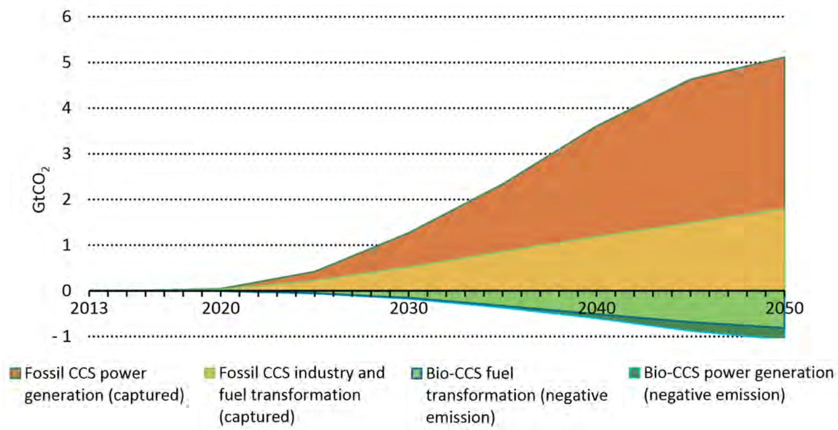


CCS is a key contributor to global emissions reductions



Source: IEA (2016), Energy Technology Perspectives 2016.

Bio-energy with carbon capture and storage (BECCS) Negative carbon dioxide emissions



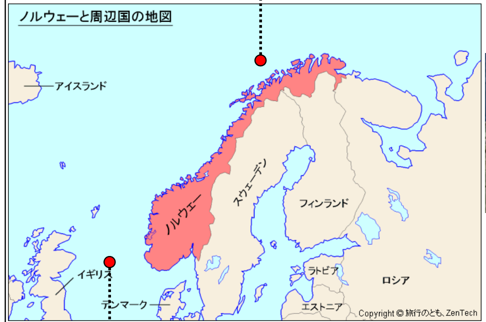
Source: IEA (2016), Energy Technology Perspectives 2016.

Large-scale CCS projects in operation

Project name	Country	Operation date	Source of CO_2	CO_2 capture capacity (mtpa)	Primary storage type
Val Verde Natural Gas Plants	US	1972	Natural gas processing	1.3	EOR
Enid Fertilizer CO_2-EOR Project	US	1982	Fertiliser production	0.7	EOR
Shute Creek Gas Processing Facility	US	1986	Natural gas processing	7.0	EOR
Sleipner CO_2 Storage Project	Norway	1996	Natural gas processing	0.9	Dedicated
Great Plains Synfuel Plant and Weyburn-Midale Project	Canada	2000	Synthetic gas	3.0	EOR
In Salah CO_2 Storage*	Algeria	2004	Natural gas processing	1.0/0.0	Dedicated
Snøhvit CO_2 Storage Project	Norway	2008	Natural gas processing	0.7	Dedicated
Century Plant	US	2010	Natural gas processing	8.4	EOR
Air Products Steam Methane Reformer EOR Project	US	2013	Hydrogen production	1.0	EOR
Coffeyville Gasification Plant	US	2013	Fertiliser production	1.0	EOR
Lost Cabin Gas Plant	US	2013	Natural gas processing	0.9	EOR
Petrobras Lula Oil Field CCS Project	Brazil	2013	Natural gas processing	0.7	EOR
Boundary Dam Carbon Capture and Storage Project	Canada	2014	Power generation	1.0	EOR
Quest	Canada	2015	Hydrogen production	1.0	Dedicated
Uthmaniyah CO_2 EOR Demonstration Project	Saudi Arabia	2015	Natural gas processing	0.8	EOR
Abu Dhabi CCS Project	United Arab Emirates	2016	Iron and steel production	0.8	EOR

Source: Global CCS Institute, data current as of end-August 2016, in IEA (2016): 20 Years of Carbon Capture and Storage - Accelerating Future Deployment

Commercial scale CO_2 storage under the seabed

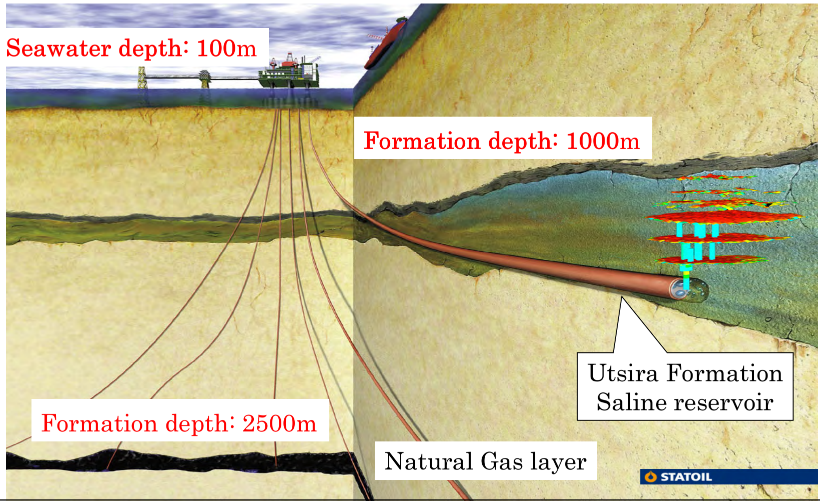


Snøhvit

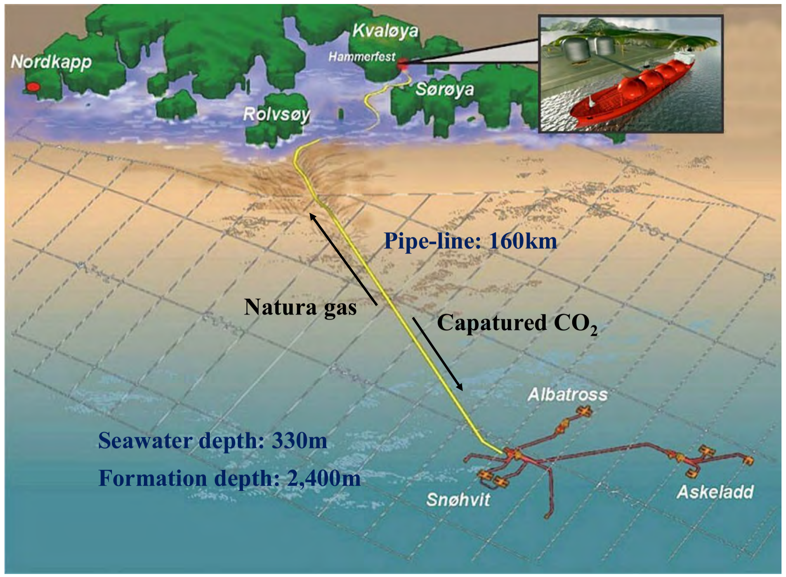
Sleipner

Sleipner project (Norway)

CO_2 Source: Gas processing



Snøhvit project (Norway)



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Lula project (Brazil)

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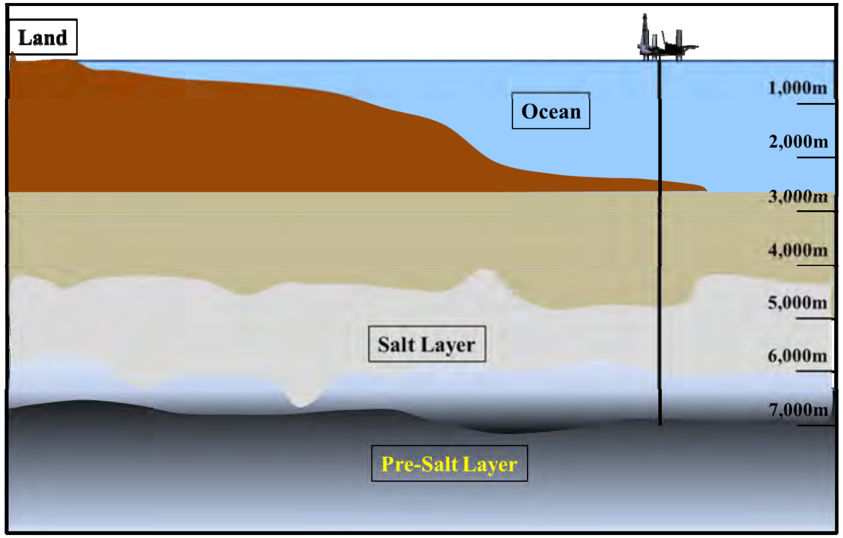
Lula project



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Tomakomai CCS Demonstration Project

- Ministry of Economy, Trade and Industry (METI)
- Japan CCS Co., Ltd. http://www.japanccs.com
- 100,000 tonnes/year or more CO_2 is to be stored under the seabed.
- CO_2 injection started in 2016 and continued to 2018.

Off-gas supply: hydrogen production facility at oil refinery plant
→ **CO_2 capture:** amine absorption
→ **CO_2 injection:** onshore
→ **Reservoirs:** under the seabed
- Sandstone layer: 1100-1200m depth
- Volcanic rocks layer: 2400-3000m depth

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Act for the Prevention of Marine Pollution and Maritime Disasters

- May 2007: The act was amended for permit procedure on dumping CO_2 stream into sub-seabed formation.
- Prevention of marine environment impact from potential CO_2 leakage

Operator of Offshore CO_2 storage,

- Shall receive permission from environment minister.
- Shall implement Environmental Impact Assessment.
- Shall monitor surrounding sea environment.

Environmental Impact Assessment (EIA) in the ACT

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Objective

- Estimation of CO_2 dispersion and its impact assessment on the assumption that stored CO_2 leaks out to the sea

Process

- Consideration of leakage scenarios and its simulation
  - CO_2 migration in the geological formation
  - CO_2 dispersion in the seawater column
- Base-line survey for the existing marine environment
- Impact assessment

Example of leakage simulations

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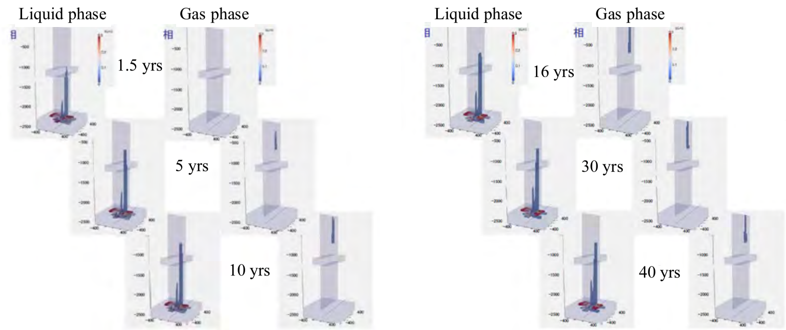
CO_2 migration in the geological formation

<u>Scenario</u>: Leakage through faults undetectable by seismic survey

<u>Simulator</u>: TOUGH2 with ECO2M (LBNL)

<u>Output</u>: CO_2 flux at the seafloor



Example of leakage simulations

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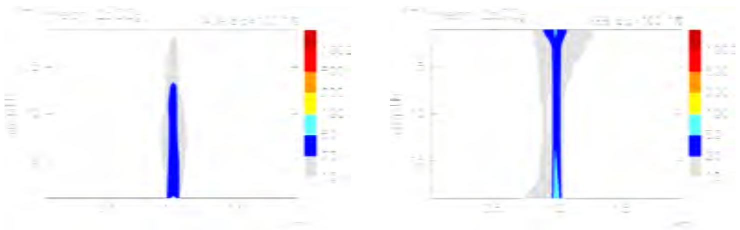
CO_2 dispersion in the seawater

<u>Input</u>: CO_2 flux at the seafloor

<u>Simulator</u>: MEC-CO2 two-phase flow model

Kano et al., 2010. Model prediction on the rise of pCO_2 in uniform flows by leakage of CO_2 purposefully stored under the seabed. International J. Greenhouse Gas Control 3, 617-625.

<u>Output</u>: CO_2 concentration gradient in the seawater column



Seawater CO_2 system

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As CO_2 dissolves in seawater,

$$CO_2 + H_2O \Leftrightarrow H_2CO_3 \Leftrightarrow HCO_3^- + H^+ \Leftrightarrow CO_3^{2-} + 2H^+$$
$$(CO_2aq)$$

Thus, to increase concentration of

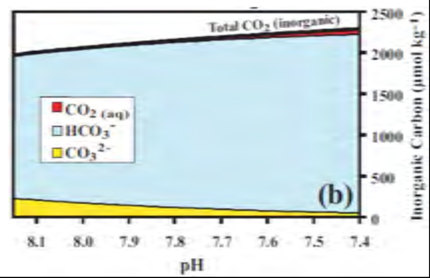
carbonic acid (H_2CO_3) ⟹ <u>*p*CO_2 increase</u>

proton (H^+) ⟹ <u>pH decrease, acidification</u>

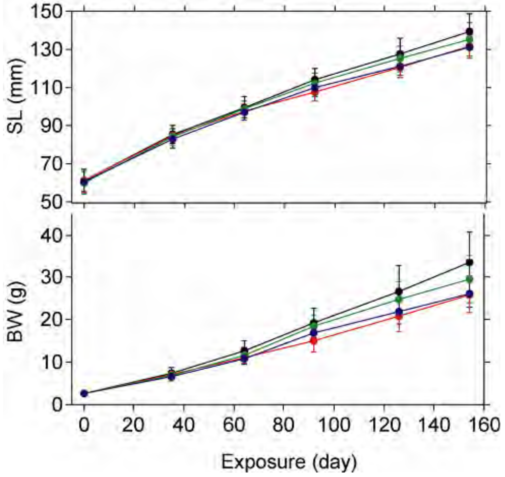
bicarbonate ion(HCO_3^-)

while decrease concentration of

carbonate ion(CO_3^{2-})



CO_2 Effects on fish growth



Kita et al. unpublished

- ●: pCO_2=400µatm (control)
- ●: pCO_2=4,000µatm
- ●: pCO_2=7,000µatm
- ●: pCO_2=12,000µatm

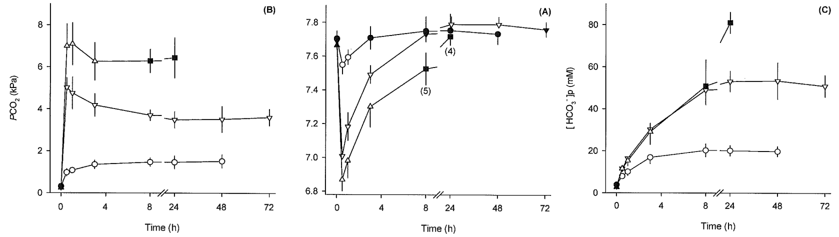
Bars represent SD.

Growth of young *Sillago japonica* under sublethal CO_2 concentration.

CO_2 effects on fish physiology

Hayashi et al. 2004.

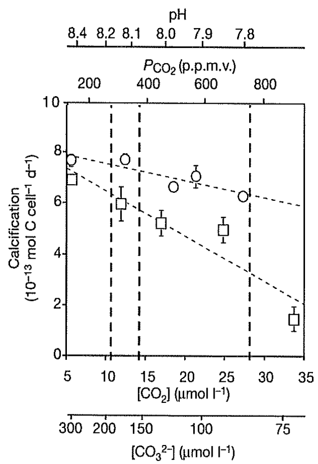
Arterial pCO_2 | Arterial pH | Plasma bicarbonate

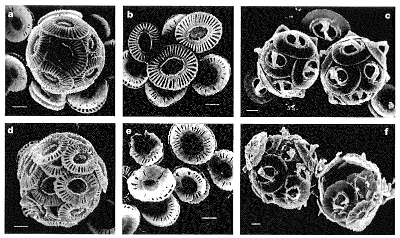


Acid-base change of Japanese flounder during CO_2 exposure of 10,000matm (●), 30,000matm (▼) and 50,000matm (▲).

Effects of high-CO_2 on coccolithophores, phytoplankton with calcite plates

Riebesell et al., 2000



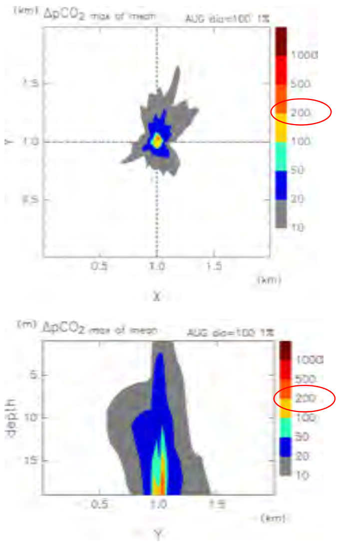


Calcification of the coccolithophorids *Emiliania huxleyi* (○) and *Gephyrocapsa oceanica* (□) as a function of CO_2 concentration.

Effects of high-CO_2 on marine organisms

Organisms	pCO_2	Effect
Calcifiers •Molluscs •Echinoderms •Corals •Coccolithophores	Δ200µatm <	Calcification decrease
Non-calcifiers •Fish •Molluscs •Copepods	Δ2,000µatm <	Physiological disturbance

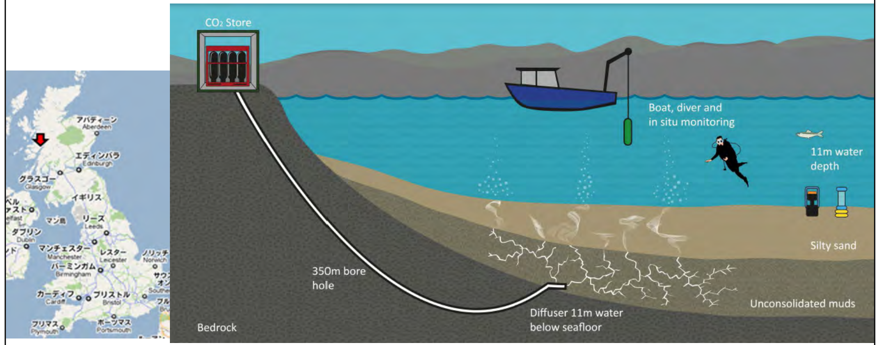
Example of estimation of ecological impacted area



- Ecological impacted area would be negligibly small even under the extreme leakage scenario

Collaboration with QICS project UK

Quantifying and Monitoring Potential Ecosystem Impacts of Geological Carbon Storage



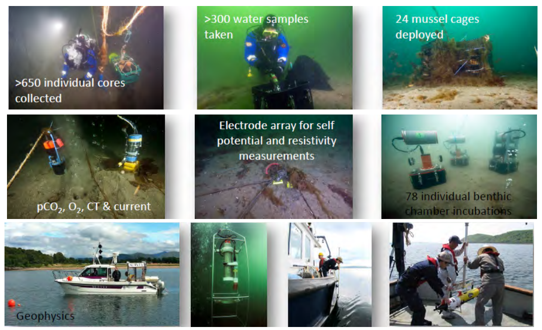
- If CO_2 leaked into the living marine environment what are the likely ecological impacts, would they be significant?
- What are the best tools, techniques and strategies for the detection and monitoring of leaks – or assurance that leakage is not happening, in the vicinity of the sea floor.

Summary from QICS

Diving surveys & sampling

In situ sensors & mesurements

Ship-board mesurements



- The biological impact was minimal and the recovery was rapid.
- Multiple monitoring methodologies in a staged approach are recommended.
- Impacts of CCS leakage should not be seen as an impediment to the development of full scale CCS.

Outputs from QICS

www.qics.co.uk

nature climate change 4, 1011-1016 (2014)

Blackford et al.

Detection and impacts of leakage from sub-seafloor deep geological carbon dioxide storage

International Journal of Greenhouse Gas Control

21 research papers

Special issue: CCS and the Marine Environment
Volume 38, July 2015

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Concluding Remarks

CCS is essential to achieve ambitious temperature target of “well below 2°C”.

Experience of commercial scale offshore CO_2 storage have pave the way for widespread deployment of CCS across power and industrial applications.

Environment impact assessment for offshore CO_2 storage:

- ✓ Important for public acceptance
- ✓ Necessitates a wider dialogue between scientists, policymakers, the public and civil society groups
- ✓ International collaboration is highly desirable

Session 2-3

"Ocean Acidification: Another Reason to Act"

Tetsuji Ida
Senior Staff Reporter,
Kyodo News

Tetsuji Ida, born in Tokyo 1959, is a graduate of Tokyo University.
He studied sociology of science and technology. Since he was assigned as a staff writer of Kyodo News in 1983, he has covered environment and development issues from the Tsukuba Science City bureau and the science news desks in the Tokyo. From 2001 to 2004, he spent 3 years in Washington bureau in the US as a science correspondent. Since 2006, he is in a current position.

He begun working on environment and development issues in 1987; one of his major subjects is climate change since he is reporting this issue before UNFCCC was formally adopted and he was a main writer of KYODO NEWS at COP3 in Kyoto.
He reported environment and poverty issues and conservation efforts on the ground in many counties in Asia, Africa and the South America.
He has covered many international conferences on multilateral environmental agreements including UNFCCC, CITES, CBD, Montreal Protocol, Ramsar Convention, WSSD in 2002 at Johannesburg, South Africa and Rio+20, Brazil in 2012. He has authored or coauthored twelve books on global warming, fisheries resources, toxic chemicals and natural resources management.

Oceans in crisis 海の危機

★Land based pollutions 海洋汚染
化学物質、リン・窒素、ﾌﾟﾗｽﾁｯｸ、放射性物質
toxic chemicals, N&P, Plastic wastes
radioactive materials

★Growing dead zone 「死の海域」の拡大

★Depleting fish stocks 漁業資源の減少

★Ocean acidification 海洋酸性化

★Temperature rise 海水温上昇

↓

GHGs emission 温室効果ガスの排出

Reducing CO2emissions
二酸化炭素の排出削減

★Reducing risks relating to climate change
気候変動のリスク削減上、極めて重要

↓

・UNFCCC in 1992
気候変動枠組み条約（1992）

・KYOTO Protocol in 1997
京都議定書（1997）

・Paris agreement in 2015
パリ協定（2015）

Reducing CO2emissions
二酸化炭素の排出削減

★"Historical" Paris agreement in 2015
「歴史的」と言われたパリ協定

Holding the increase in the global average temperature to **well below 2°C** above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels,

気温上昇を2度未満～1．5度を目指す

In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, and to undertake rapid reductions .so as to **achieve a balance between anthropogenic emissions by sources and removals by sinks** of greenhouse gases in the second half of this century

今世紀後半に実質的に「排出ゼロ」に

Reducing CO2emissions
二酸化炭素の排出削減

★"Historical" Paris agreement in 2015

「歴史的」と言われるパリ協定

Each Party shall prepare, communicate and maintain successive **nationally determined contributions** that it intends to achieve. Parties shall pursue domestic mitigation measures with the aim of achieving the objectives of such contributions.

各国が目標・取り組みを提出・達成目指す義務

Entry into force on Nov. 4th.Ratified by 122 countries

既に122カ国が批准・15年11月4日に発効

Reducing CO2emissions
二酸化炭素の排出削減

★"Historical" Paris agreement in 2015

「歴史的」と言われるパリ協定

Big gap between pledged reduction and necessary amount.

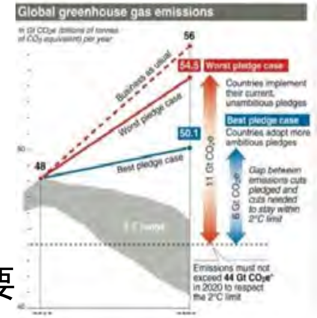
2度目標達成のためには

今の目標では足りない

↓

More ambition needed

削減目標を上積みする必要



OA issue in post PA era
パリ協定後の海洋酸性化問題

★less scientifically uncertain

科学的な不確実性は少ない～必ず起こる

★Existence of huge inertia in the ocean

効果が出るまでに長い時間がかかる

★Oceans are already under sever stresses

海の環境は既に深刻・危機的状況にある

★Some areas are very vulnerable

特に影響を受けやすい場所がある

3. 海の状況

海は酸性化している

- 海洋は排出された人為起源の二酸化炭素の約30%を吸収し、海洋酸性化を引き起こしている (IPCC AR5 WG I SPM p.11, 28-29行目)
- 海面付近の海水のpHは工業化時代の始まり以降、0.1低下している（高い確信度） (IPCC AR5 WG I SPM p.12, 11-12行目)

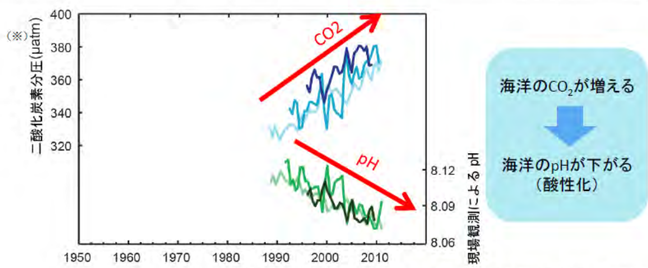


図. 海面の二酸化炭素とpH

線の色の違いは使用している観測データの違い。

（※）大気と海洋の間でのやり取りされる二酸化炭素の量を定量的に扱う場合には、二酸化炭素濃度の単位を圧力の単位で示す。これを二酸化炭素分圧と呼び、μatm（100万分の1気圧）で表す。

出典：図, IPCC AR5 WG I SPM Fig. SPM.4(b)

環境省　18

10. 将来の海の予測

海の酸性化はさらに進行する

- 海洋による炭素貯留の増加が、将来において、酸性化を進めるであろうことはほぼ確実である

(IPCC AR5 WG I TS p.94, 1-2行目)

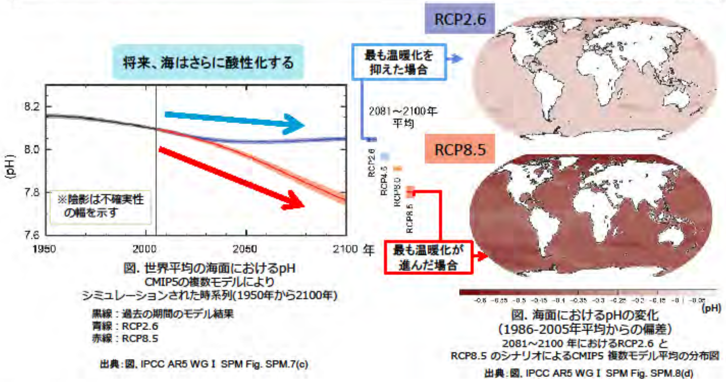
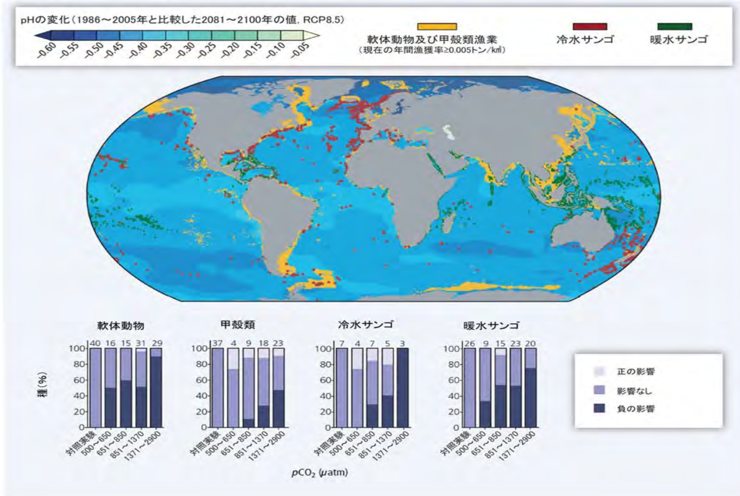


図. 世界平均の海面におけるpH CMIP5の複数モデルにより シミュレーションされた時系列(1950年から2100年)
黒線：過去の期間のモデル結果
青線：RCP2.6
赤線：RCP8.5
出典：図. IPCC AR5 WG I SPM Fig. SPM.7(c)

図. 海面におけるpHの変化 (1986-2005年平均からの偏差) 2081～2100 年におけるRCP2.6 と RCP8.5 のシナリオによるCMIP5 複数モデル平均の分布図
出典：図. IPCC AR5 WG I SPM Fig. SPM.8(d)

環境省　42



High risk in polar region and small island states
将来のリスクは特に極域と小島しょ国で大きい

OA issue in post PA era
パリ協定後に考える海洋酸性化問題

★AO and Japan

・Japan as an Inland state
　そもそも日本は島国

・Huge EEZ area
　広大な排他的経済水域（EEZ）

・Heavenly dependent on the ocean
　海に多くを依存している

OA issue in post PA era
パリ協定後に考える海洋酸性化問題

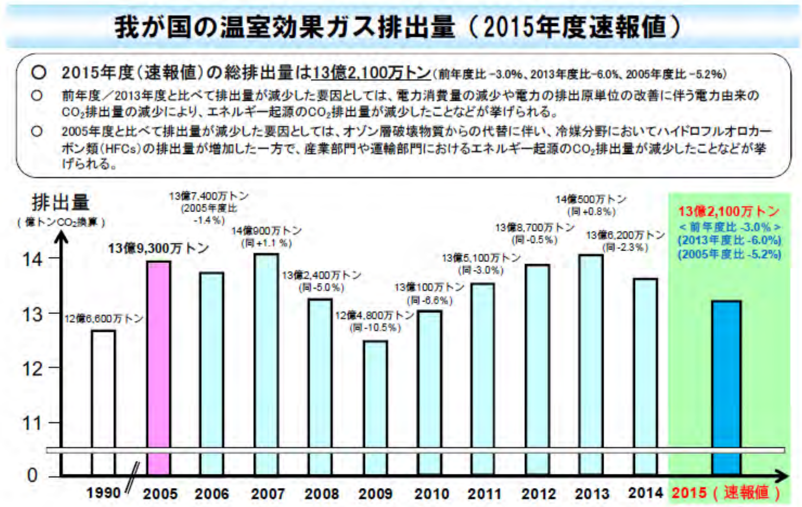
★AO issue : another important reason to act to emissions reduction
一層の排出削減を進めるべきもう一つの根拠

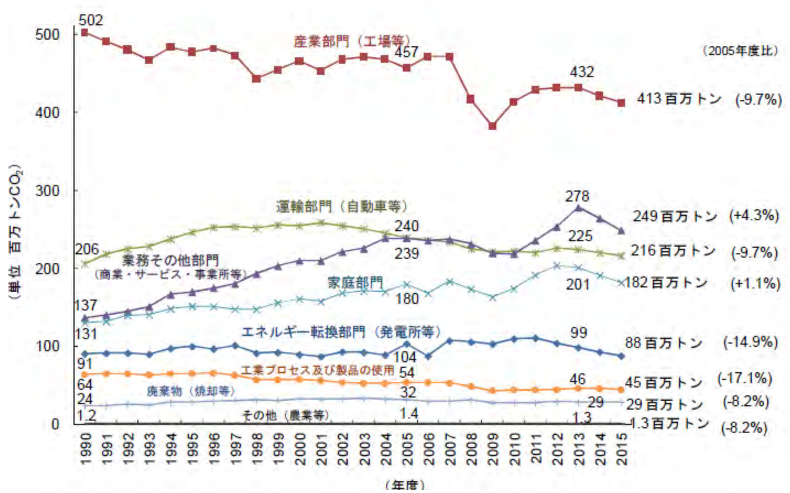
★Target : **well below 2°C to 1.5°C**
a balance between emissions and removals
目指すべきは「実質的に排出ゼロ」の社会

★post PA era = the end of fossil fuel era
化石燃料時代の終わりの始まり

CO2 reduction in Japan
日本の二酸化炭素排出削減

★**Growing emissions since 1990**
1990年以降、つい最近まで減っていない
★No reduction from industrial sector
Growing emissions from offices and houses
進まない産業界の削減＆
家庭･オフィスの排出増
★Impact of Fukushima disaster in 2011
東京電力福島第1原発事故の影響





CO2 reduction in Japan
日本の二酸化炭素排出削減

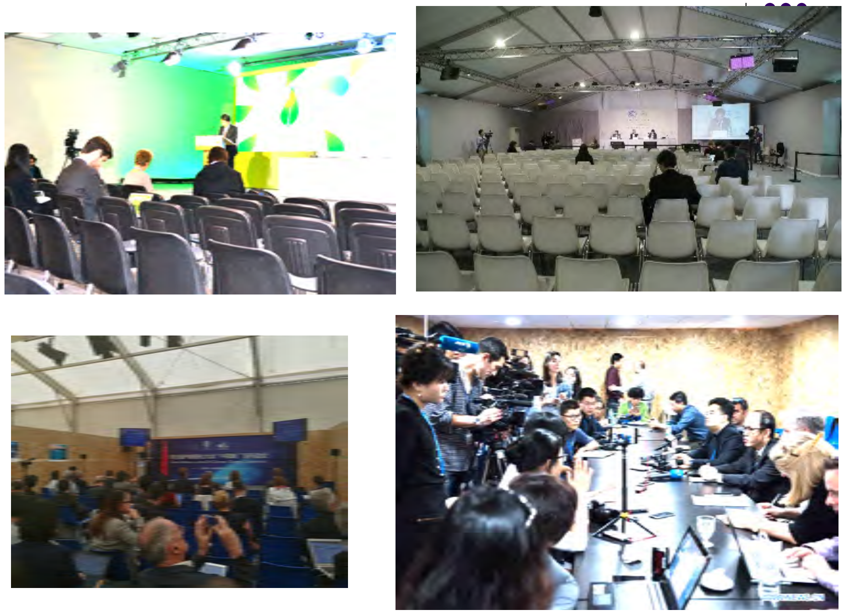
★**Growing emissions since 1990**
1990年以降、つい最近まで減っていない
★Less active in the negotiation since COP16
COP16（2010）～交渉で消極姿勢
★**Less ambitious reduction target**
小さい削減目標
2020 ▲3.8% cf 2005 (+3.1% cf 1990) with no nuke
2015 ▲5.2% cf 2005 /already achieved!!

CO2 reduction in Japan
日本の二酸化炭素排出削減

★We are not a key player in the negotiation anymore.
もはや、温暖化交渉の主役ではない

↓

★That's lead to "Japan passing"
日本パッシングの始まり



OA issue in post PA era
パリ協定後に考える海洋酸性化問題

★Let AO issue as a driver of policy change to achieve deep CO_2 emission reduction.
海洋酸性化問題をきっかけにより積極的な排出削減対策に

★Taking back leadership role in the climate diplomacy.
温暖化外交でのリーダーシップを再び

★A lot of reason, lot of things to do and we have a potential
やるべきこと、やれることはたくさんある

OA issue in post PA era
パリ協定後に考える海洋酸性化問題

★A lot of reason to act, lot of things to do and... we have a potential

やるべきこと、やれることはたくさんある

・Scientific research monitoring planning, adaptation in high risk area….

科学研究やﾓﾆﾀﾘﾝｸﾞ、ﾊｲﾘｽｸな場所での適応

・Most importantly…CO_2 reduction and Aid to vulnerable countries like SIDS.

何よりも大幅な排出削減＆途上国援助

Session 2-4　Moderator Speech

Discussion
“Measures for Converting Response into Policy”

Joji Morishita
Professor,
Tokyo University of Marine Science and Technology

He was Director-General of Japan’s National Research Institute of Far Seas Fisheries from 2013 to April 2016.
He is Japan’s Commissioner to and Chair of the International Whaling Commission (IWC).
He also serves as Chair of the Scientific Committee of the North Pacific Fisheries Commission (NPFC).
He represented Japan at the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR), the Meeting on High Seas Fisheries in the Central Arctic Ocean, and other international ocean and environmental meetings including the Convention on Biological Diversity, CITES, and UN organized meetings.
He has been involved in international fisheries issues since 1982 in the Japanese Government and served the Japanese Embassy in the United States from 1993 to 1996. PhD (Agriculture), Kyoto University, Master of Public Policy (MPP), Harvard University. BS, Kyoto University.

Discussion Topics of Session 2;

1. What are the policy objectives for ocean acidification?

Prevention, Adaptation, Monitoring/Assessment and/or their combination? We need an agreement on plans and priorities. Do we need an international instrument to confirm the agreement?

2. Do we have a system/organization to implement the policy?

Problems caused by ocean acidification needs to be addressed by some governments/international organizations/non-governmental organizations. However, do we have such a system/organization that can handle the problems? It could be compartmentalized, divided, insufficient, or even non-existent. Who will take the lead?

3. How can we inform and persuade stakeholders, including decision makers, to take actions?

Scientific information can be highly technical, could involve uncertainties, and may convey no urgency. Information needs to be processed into a "digestive" form with a right message for the stakeholders. Who are the stakeholders?

4. Where are the resources to address this challenge?

Depending on the policy objectives and measures to implement them, necessary financial and organizational resources, including expertise, have to be secured.

5. Road map

Necessary steps need to be identified. Milestones. Triggers for next steps. Time scope.

Session 3-1

"Synthesis of Information on North Pacific Ocean Acidification Studies by the North Pacific Marine Science Organization (PICES)"

Tsuneo Ono
Chief Scientist,
Japan Fisheries Research and Education Agency (FRA)

Research Interests

*Temporal variation of physical/chemical ocean environment both by natural and by anthropogenic forcings, such as PDO and/or global warming
*Response of oceanic ecosystems to ocean environmental changes
*Carbon and nutrient cycles within North Pacific Ocean

Education

1997	Ph.D. in Fisheries Sciences, Hokkaido Univ.

Synergistic Activities

2004-2006	Contributing Author for IPCC Fourth Assessment Report
2006-present	Member of PICES Section for Carbon and Climate (co-chair from 2015)

Synthesis of information on North Pacific ocean acidification studies by
North Pacific Marine Science Organization (PICES)
PICESによる北太平洋域の酸性化情報収集活動

PICES countries:
- United States
- Canada
- Russian Federation
- Republic of Korea
- Japan
- People's republic of China

Section on Carbon and Climate (S-CC)

- formed at 2005 annual meeting in Vladivostok to continue work of WG's 13 and 17
- 22 members representing all PICES countries
- parent committees are POC and BIO
- major accomplishments to date include the Best Practices Guide; PACIFICA data synthesis; topic sessions at 2007, 2009, 2012, 2013, 2015, 2016 annual meetings

S-CC activities 2014-2016

- Three-year ongoing work: Basin-scale assessment of Ocean Acidification

  # Information collection completed in previous Workshop (Nov. 3, W1), table of contents fixed

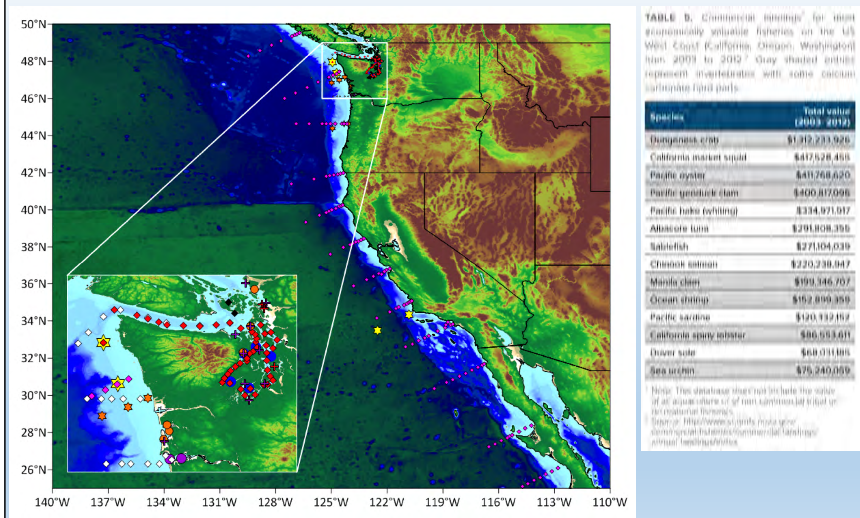
  # will be published in 2017 as PICES Scientific Report
  Request for funds approx. 10 k $ and technical support to POC/BIO

- Two workshops, two session and two ICES/PICES joint workshop / session during 2014 – 2016

  # in 2016: PICES - W1 "Acidification of the North Pacific Ocean: a basin-wide assessment"
  PICES - S7 "New Stage of Ocean Acidification Studies: Responses of Oceanic Ecosystem including Fisheries Resources"

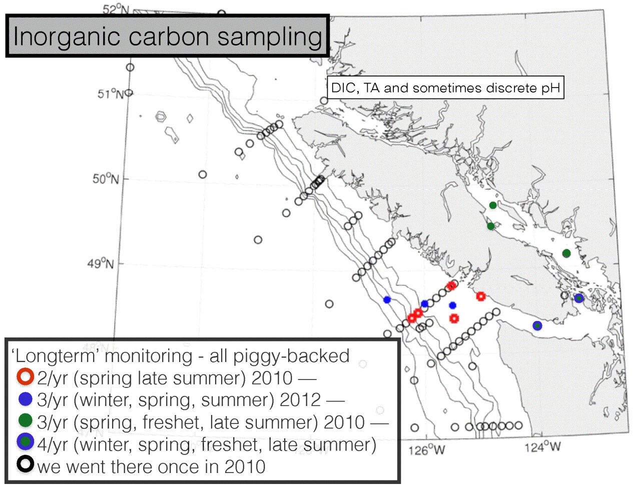
  ICES/PICES joint workshop on understanding the impacts and consequences of ocean acidification for commercial species and end-users (WKACIDUSE)
  Dec. 5-9, ICES headquarters (Copenhagen, Denmark)

A *nested* West Coast OA/multi-stressor observing network



[Alin et al., 2015]

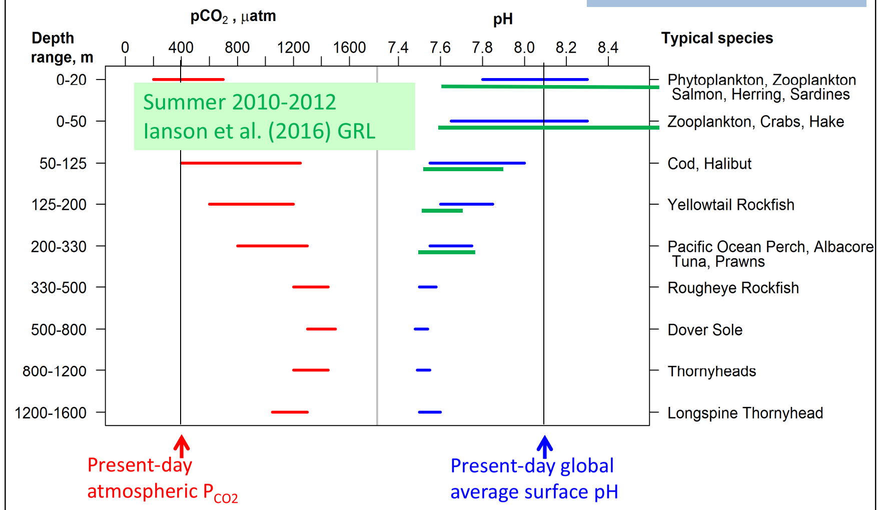
Field observations in Canada(courtesy D. Ianson)



Haigh-Holt, PICES 2016 S7

West coast of Vancouver Island (offshore) and Straight of Georgia (inshore)

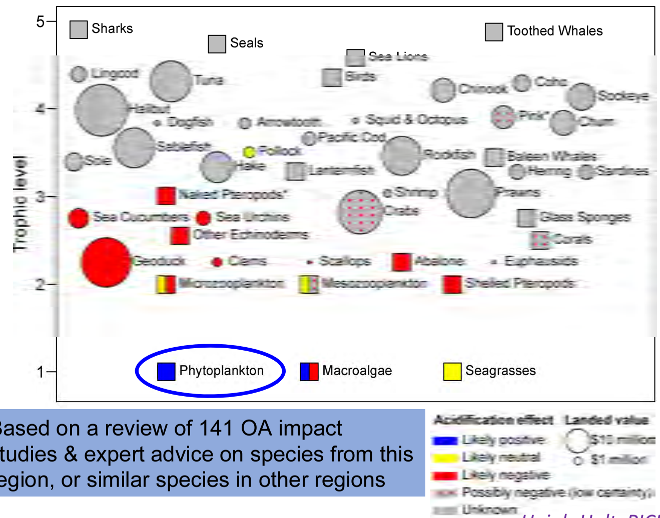
Summer 2010
Ianson, unpublished data
after Fig. 2 Haigh et al. (2015)



Haigh-Holt, PICES 2016 S7

Wild species groups

Haigh et al. (2015) PLOS ONE

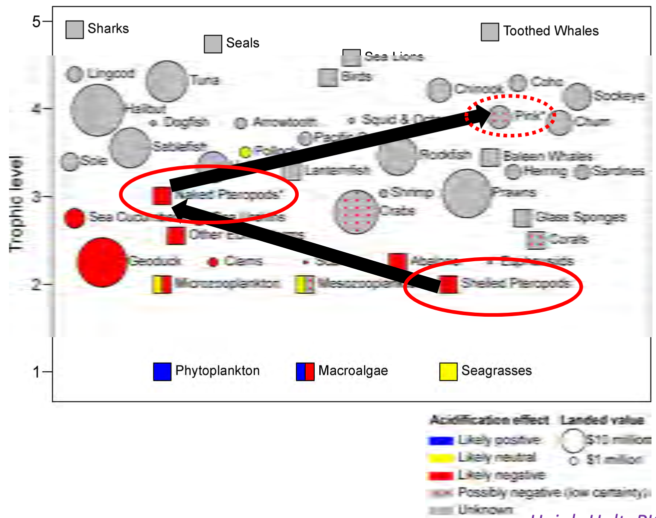


Based on a review of 141 OA impact studies & expert advice on species from this region, or similar species in other regions

Haigh-Holt, PICES 2016 S7

Fish:indirect effects

Haigh et al. (2015) PLOS ONE



Haigh-Holt, PICES 2016 S7