‘ADRIFT’

(Assessing the Debris-Related Impact from Tsunami) project

– outline and legacy products –

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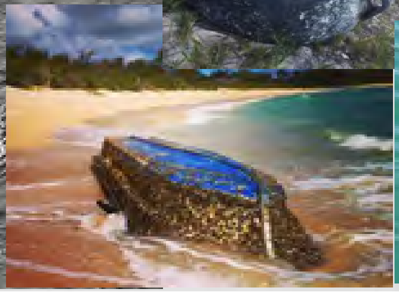
Fisheries and Oceans Canada / Pêches et Océans Canada

NIES JAPAN

環境省 Ministry of the Environment

PICES



東日本大震災と津波
GREAT EAST JAPAN EARTHQUAKE AND TSUNAMI

2011年3月11日にマグニチュード9.0の地震が発生し，最大39メートルもの高さの津波が360 km以上の東北地方の太平洋沿岸を襲った。

On March 11, 2011, a great earthquake with a magnitude of 9.0 hit the country of Japan and triggered a tsunami with waves up to max. 39 meters (130 feets) over (360 km) 200 miles of coastal line of East North of Japan mainland (*Honshu*) facing the Pacific Ocean.

Photo credit: National Geographic

津波起因海洋漂流物
JAPAN TSUNAMI MARINE DEBRIS ("JTMD")

500万トン以上のものが海に流され，太平洋上をさまよい始めた。

An estimated 5 million tonnes of debris was washed away and began drifting east across the Pacific Ocean.

Photo credit: U.S. Navy

Photo credit: Bloomberg

PERSPECTIVES

環境省による拠出金事業

Funded by Ministry of the Environment (MoE)

日本政府　Government of Japan

実施期間:2014年7月－2017年3月

Duration: July 2014 – March 2017

プロジェクトで実施した各課題
RESEARCH THEMES

1. Modelling

   震災起因の海洋漂流物の移動の軌跡予測モデルシミュレーション

2. Surveillance and Monitoring

   漂流・漂着物のモニタリング調査

3. Risk of Invasive Species

   漂流・漂着物に伴う移入種のリスク評価

海洋漂流物のモデルシミュレーション

Model Simulation of Japan Tsunami Marine Debris (JTMD)

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INTERNATIONAL PACIFIC RESEARCH CENTER
IN THE SCHOOL OF OCEAN AND EARTH SCIENCE AND TECHNOLOGY AT THE UNIVERSITY OF HAWAI'I AT MANOA

N. Maximenko, J. Hafner, (ハワイ大学Univ. Hawaii IPRC)
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石川 洋一 (海洋研究開発機構JAMSTEC)
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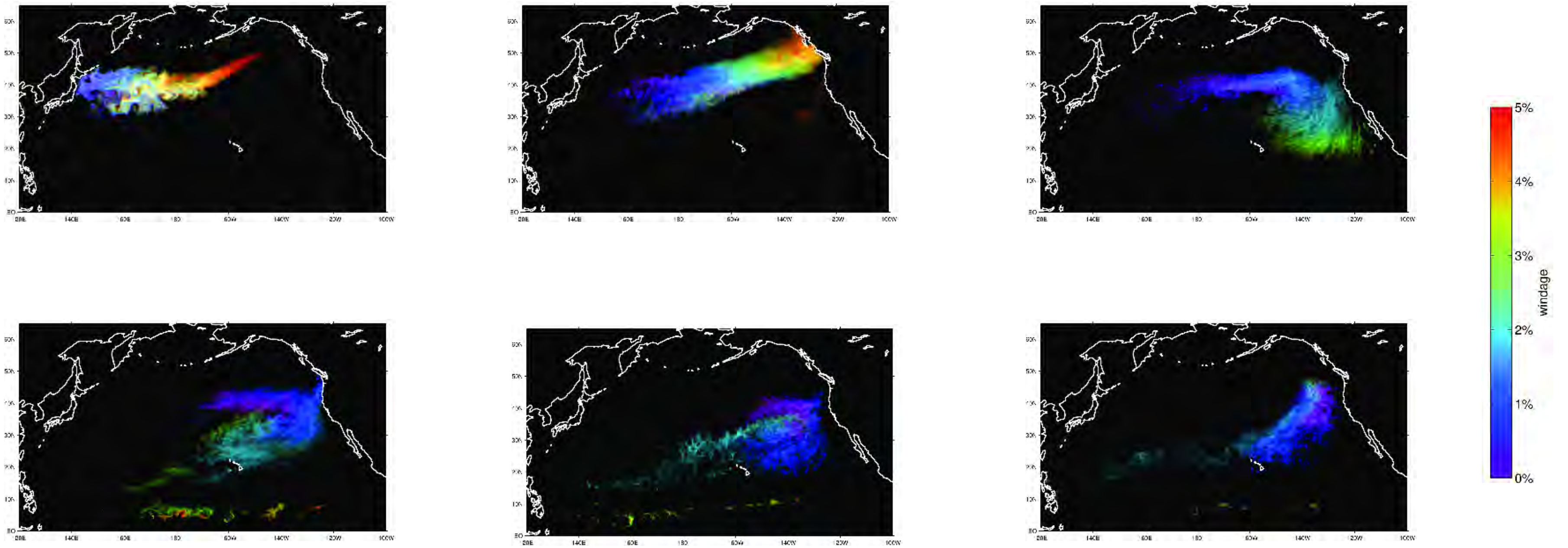
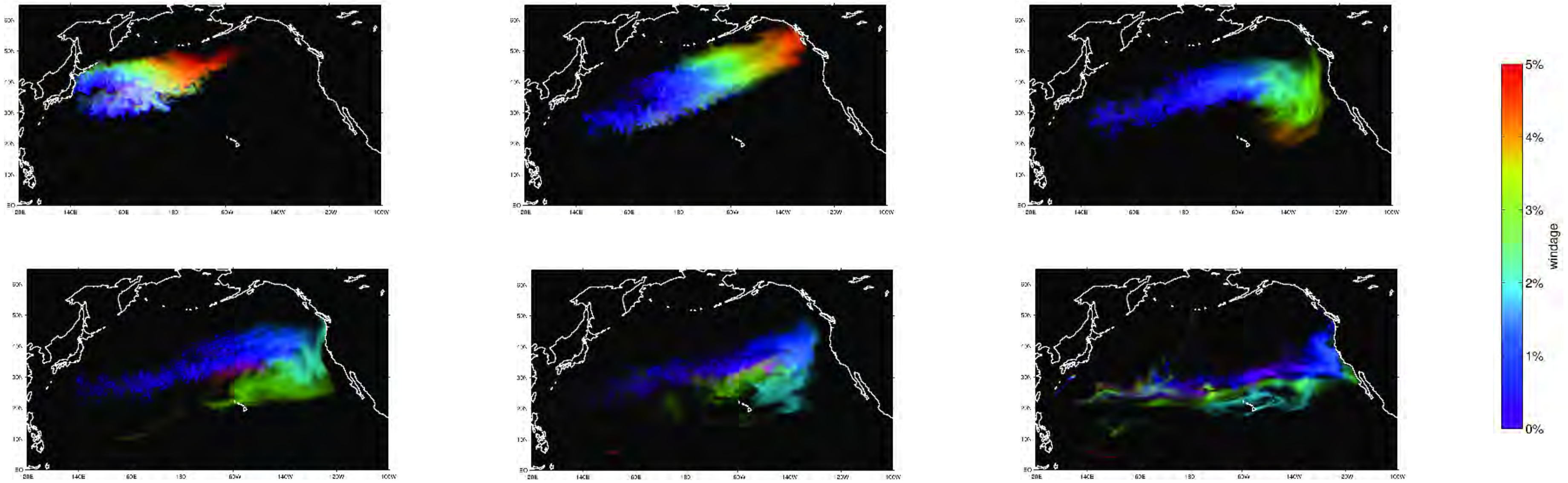
国立研究開発法人 日本原子力研究開発機構 Japan Atomic Energy Agency

様々なモデルの比較
Inter-comparison of various models

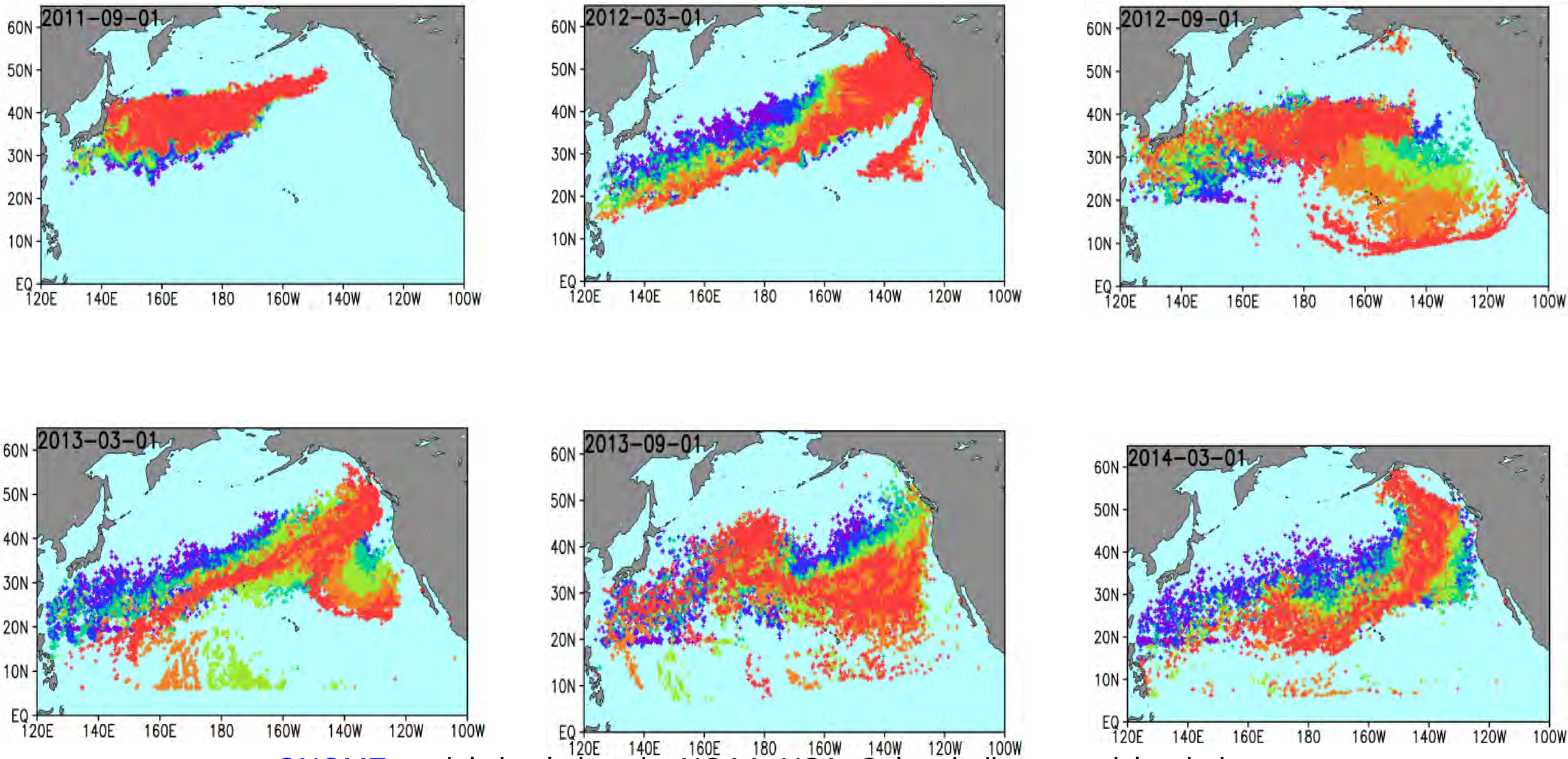


SCUD モデル（ハワイ大IPRC） SCUD model simulations by Hawaii Univ., IPRC

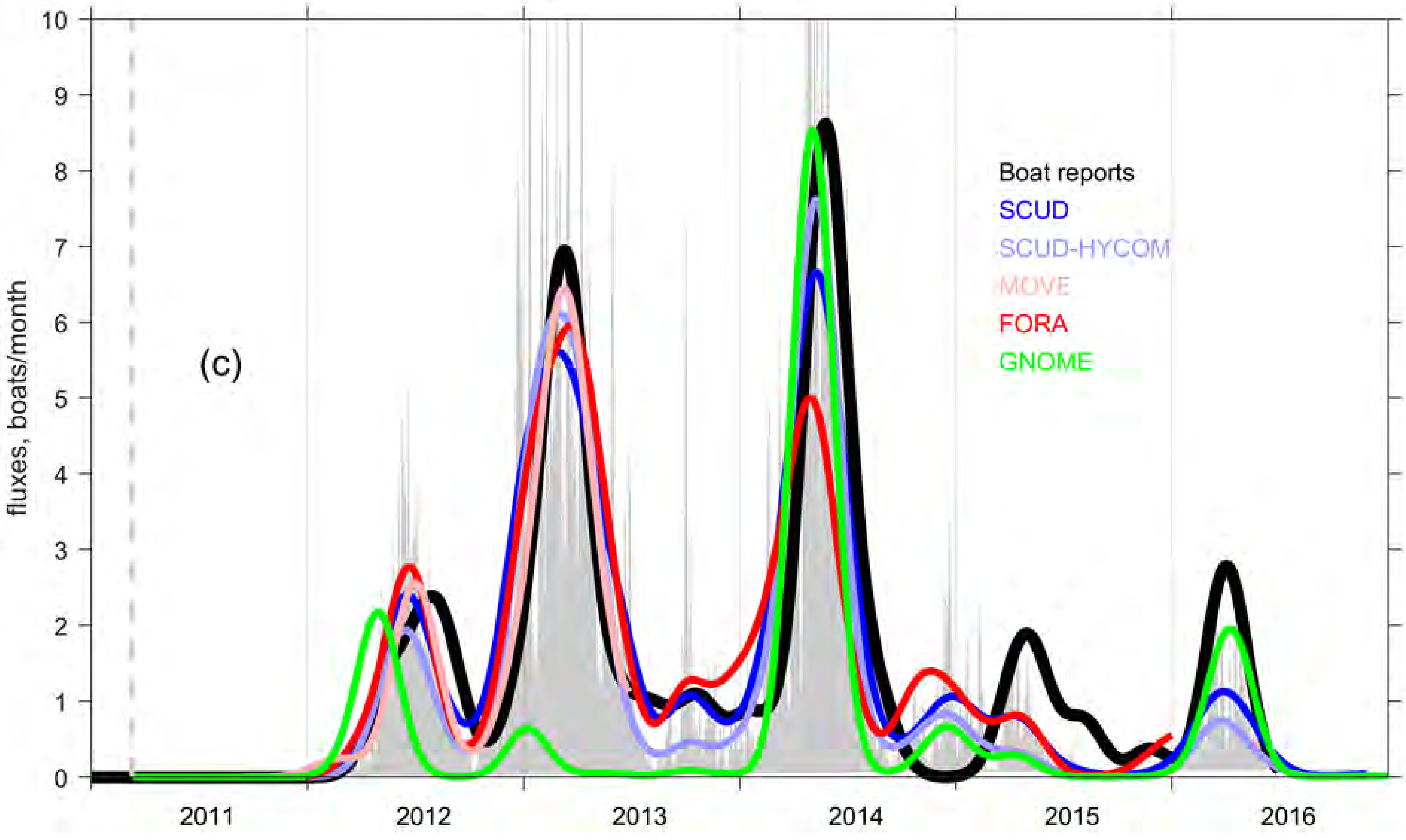


MOVE/K-7/SEA-GEARN モデル（日本合同チーム） MOVE/K-7/SEA-GEARN model simulations（Japan）

米国海洋大気庁(NOAA）のシミュレーションシステム(GNOME)による結果



GNOME model simulations by NOAA, USA. Colors indicate particle windages



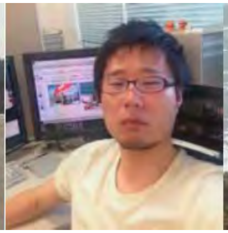
日米複数のモデル（SCUD、GNOME、SEA-GEARN/MOVE-K7）による漂着物のシミュレーション結果と、北米西海岸における小型船舶漂着発見状況との比較

JTMD boat observations (black line) and scaled model fluxes on the North America west coast for multi-windage approximation with windage distribution.
Lines present timelines, smoothed with a Gaussian filter of 1.5-month half-width.
Grey background shows unsmoothed scaled SCUD solution at optimal windage.
Vertical dashed gray line marks the moment of the tsunami. Units are number of boats per a month.

北米西海岸設置のウェブカメラによる漂着物挙動解析
Webcam monitoring of landed marine debris

磯辺篤彦 Atsuhiko Isobe (Research Institute for Applied Mechanics [RIAM], Kyushu Univ)

岩﨑慎介・油布圭(RIAM)，加古真一郎(鹿児島大)，片岡智哉(東京理科大)
Charlie Plybon (Surfrider Foundation OR), Thomas A. Murphy (Oregon State Univ)
and Nir Barnea (NOAA, Marine Debris Program)





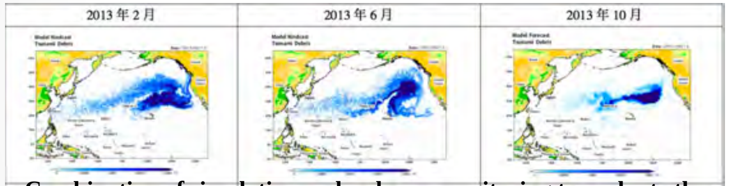



私たちの戦略 Our strategy

「震災漂着物が運ぶ外来生物は、北米ハワイの海洋・海岸生物に脅威となるか？」

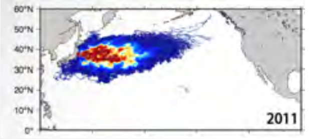
そもそもinvasive species は震災漂着物でなくても運ばれるもの。
震災漂着物由来に限定した環境影響評価ができるのか？
→ 震災漂着物の漂着場所や時期を特定することが重要

震災漂着物の漂流経路再現は、大気や海洋の同化プロダクト＋粒子追跡モデルで、そこそこいけるはず(下は震災直後に環境省が発表したもの[JAMSTEC,気象研,京都大])。
ただ海岸漂着までは解像できず(波浪や海浜流)、あくまで沖合漂流量の推定である。
また再漂流も表現できず、漂着と再漂流を繰り返す海岸漂着量の評価は難しい。



Combination of simulation and webcam monitoring to evaluate the abundance of JTMD

大気や海洋の同化プロダクト＋粒子追跡モデル



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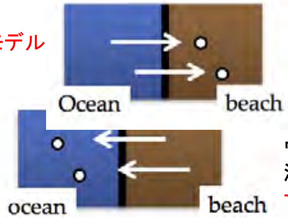
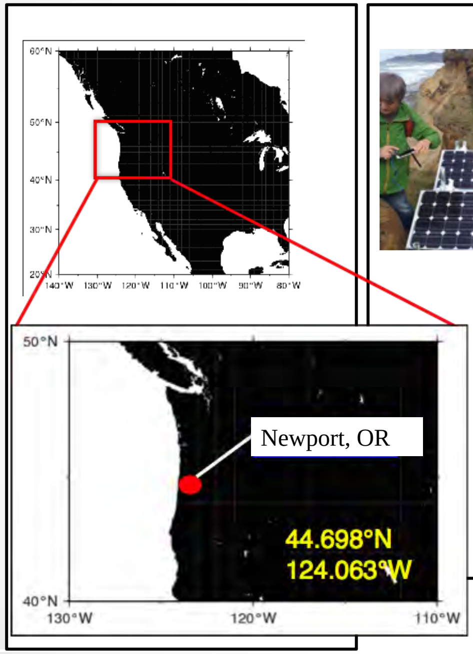


空撮画像(NOAA)によるモデルの妥当性評価

ウェブカメラで監視したゴミ漂着量と海況・風況データを比較し
サブモデルを構築、これを組み合わせる。

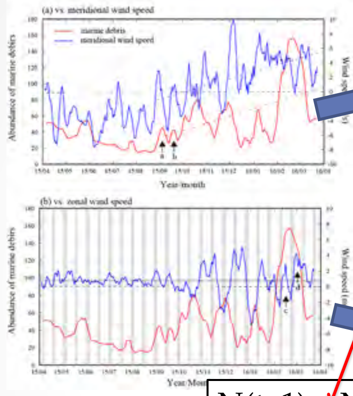


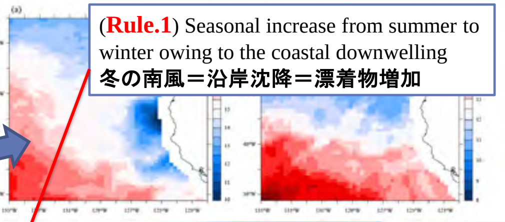
interval：
9:00~18:00 once at each hour

resolution：
1920 × 1080 pixels

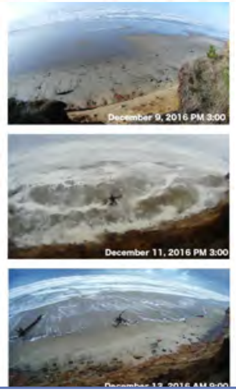
period：
2015/Apr～on-going

Summary of webcam monitoring
Kako et al., (submitted)



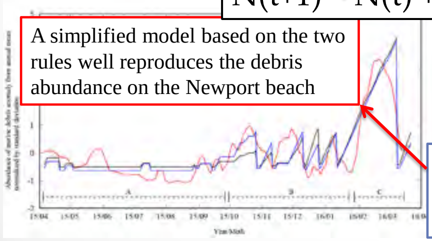


(**Rule.1**) Seasonal increase from summer to winter owing to the coastal downwelling
冬の南風＝沿岸沈降＝漂着物増加



$$N(t+1) = N(t) + \alpha R(t)$$

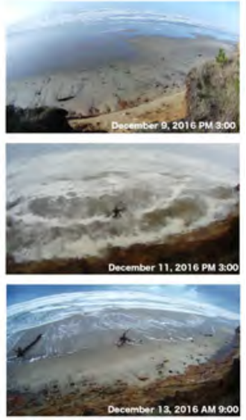
A simplified model based on the two rules well reproduces the debris abundance on the Newport beach

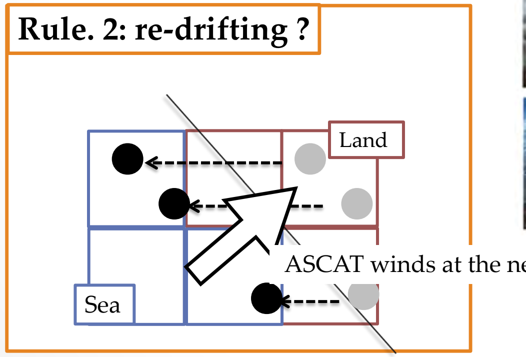


(**Rule.2**) Rapid decrease owing to the wind setup (at spring tides) during the westerly (onshore-ward) winds
大潮での向岸風＝潮位の増加＝再漂流

サブモデル
岸向きの風が強い大潮時に、岸に漂着した仮想粒子を海に戻す

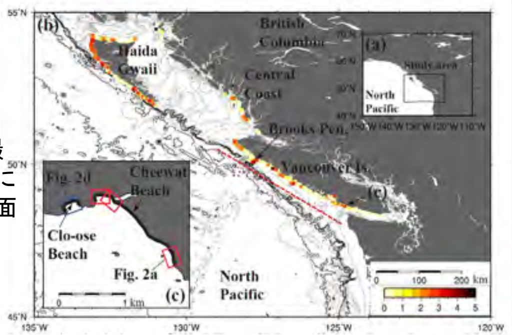
When intense **onshore-ward winds** (> average + SDV) occurred at **spring tides** (i.e., the occurrence of the **wind setup**), all debris “littered” on land cells returns to the oceanic cells.

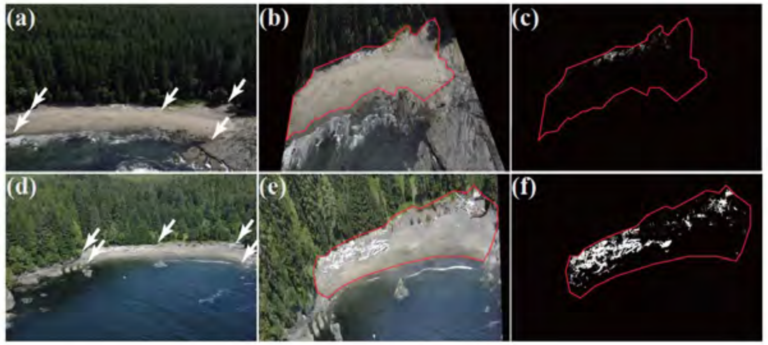




Model validation with aerial photography using a Cessna plane

Kataoka et al. (submitted)
北米西海岸のセスナ機による海岸空撮写真を射影変換処理してデカルト座標に落とし込み、漂流物の被覆面積と海岸面積の比を求めた。Using the aerial photographs, we computed the ratio between areas of beach litter and beaches



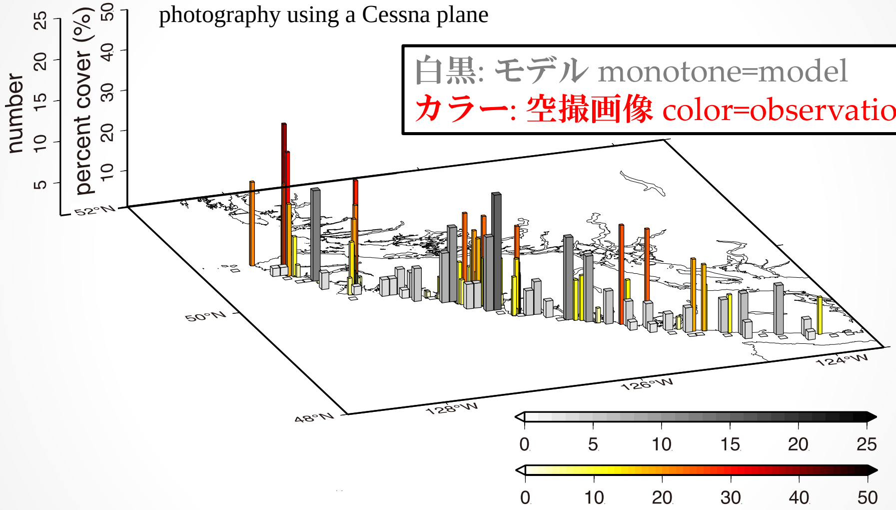


観測データとの比較

2014/10/7, 2014/12/3

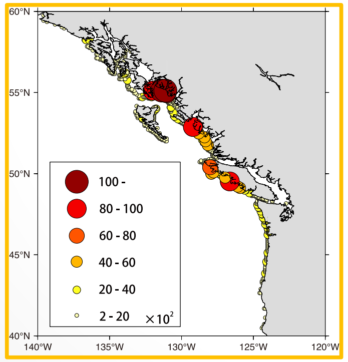
Model validation with aerial photography using a Cessna plane

白黒: モデル monotone=model
カラー: 空撮画像 color=observation



Conclusions

- A webcam-based sub-model was combined with a particle tracking model to estimate the abundance of 3.11 tsunami debris washed ashore on the US and Canadian beaches.
- In total, 30,000 tons (2%) of debris potentially exist on the beaches at the present time.
- The model result states that the invasive spices carried by tsunami debris were unlikely to wash ashore widely on the entire US and Canadian beaches. They have been washed ashore on the relatively narrow area (<1000 km) around the south of BC and the north of WA, which might act as a "gate" of the invasive spices carried by the tsunami debris.



震災漂流物のうち2%程度が、米国とカナダの国境1000km程度の海岸に集中して漂着したことが示唆された。この場所で日本原産の「外来種」が多く確認されるならば、それは震災漂流物が運んだ可能性が高い。

The Transport of Marine Life Across the Ocean on Tsunami Marine Debris

東日本大震災による津波にともなう漂着物がもたらした海洋無脊椎動物の越境移動について

James T. Carlton (Williams College, USA)

Williams

John Chapman — Oregon State University

Jonathan Geller — Moss Landing Marine Laboratories

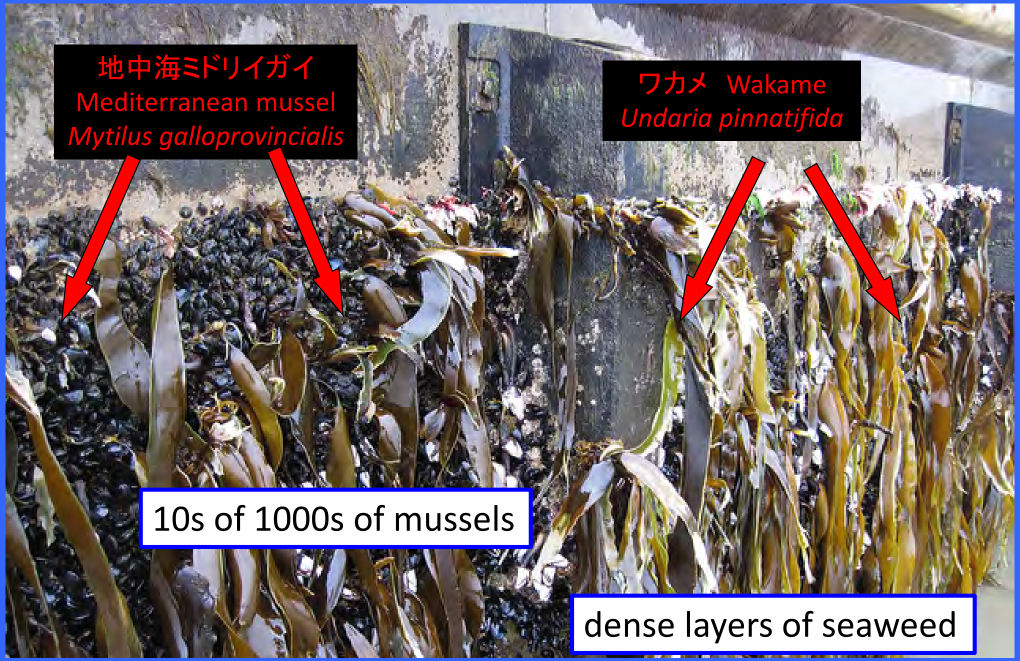
Jessica Miller — Oregon State University

Gregory Ruiz — Smithsonian Environmental Research Center

OSU Oregon State University

NSF

Sea Grant Oregon



Examples of coastal organisms on "Misawa 1": Landed Agate Beach, Oregon, June 4, 2012

「移入種」として良く知られた生物が見つかった

Some of these species were well-known "invasive" species

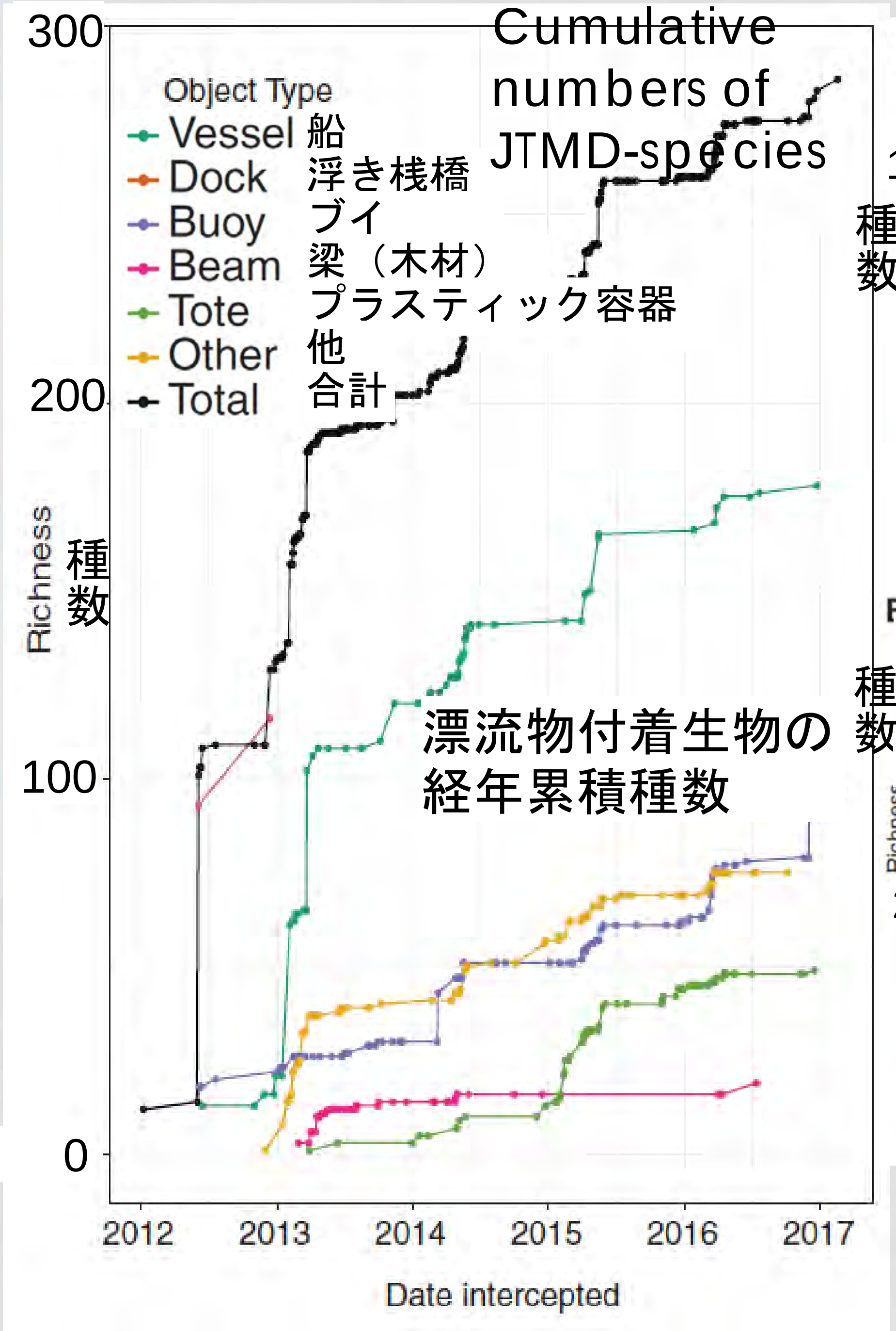
RESEARCH

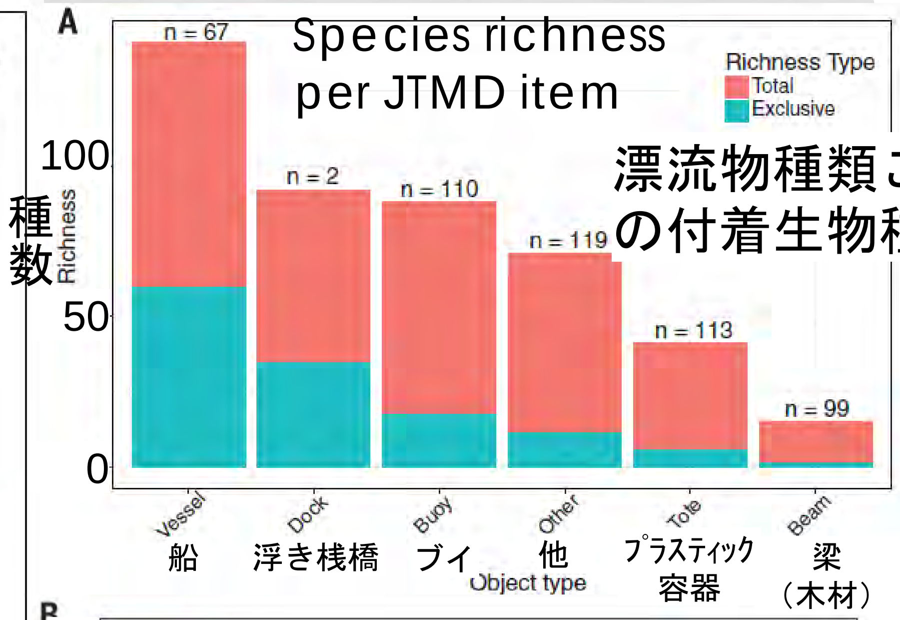
BIOGEOGRAPHY

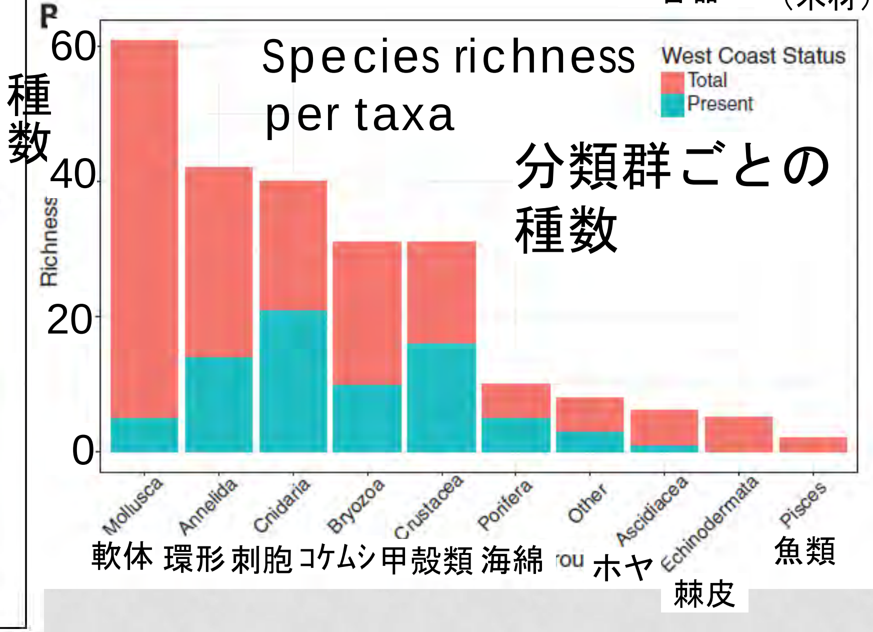
Tsunami-driven rafting: Transoceanic species dispersal and implications for marine biogeography

James T. Carlton,[1,2*] John W. Chapman,[3] Jonathan B. Geller,[4] Jessica A. Miller,[3] Deborah A. Carlton,[1] Megan I. McCuller,[1†] Nancy C. Treneman,[5] Brian P. Steves,[6] Gregory M. Ruiz[6,7]

The 2011 East Japan earthquake generated a massive tsunami that launched an extraordinary transoceanic biological rafting event with no known historical precedent. We document 289 living Japanese coastal marine species from 16 phyla transported over 6 years on objects that traveled thousands of kilometers across the Pacific Ocean to the shores of North America and Hawai'i. Most of this dispersal occurred on nonbiodegradable objects, resulting in the longest documented transoceanic survival and dispersal of coastal species by rafting. Expanding shoreline infrastructure has increased global sources of plastic materials available for biotic colonization and also interacts with climate change–induced storms of increasing severity to eject debris







漂着物付着生物の多様性 － 海藻 －

川井浩史・羽生田岳昭（神戸大学）

ゲイル ハンセン（オレゴン州立大）

Species and genetic diversity of seaweeds on Japanese tsunami debris

Hiroshi Kawai & T. Hanyuda (Kobe University)

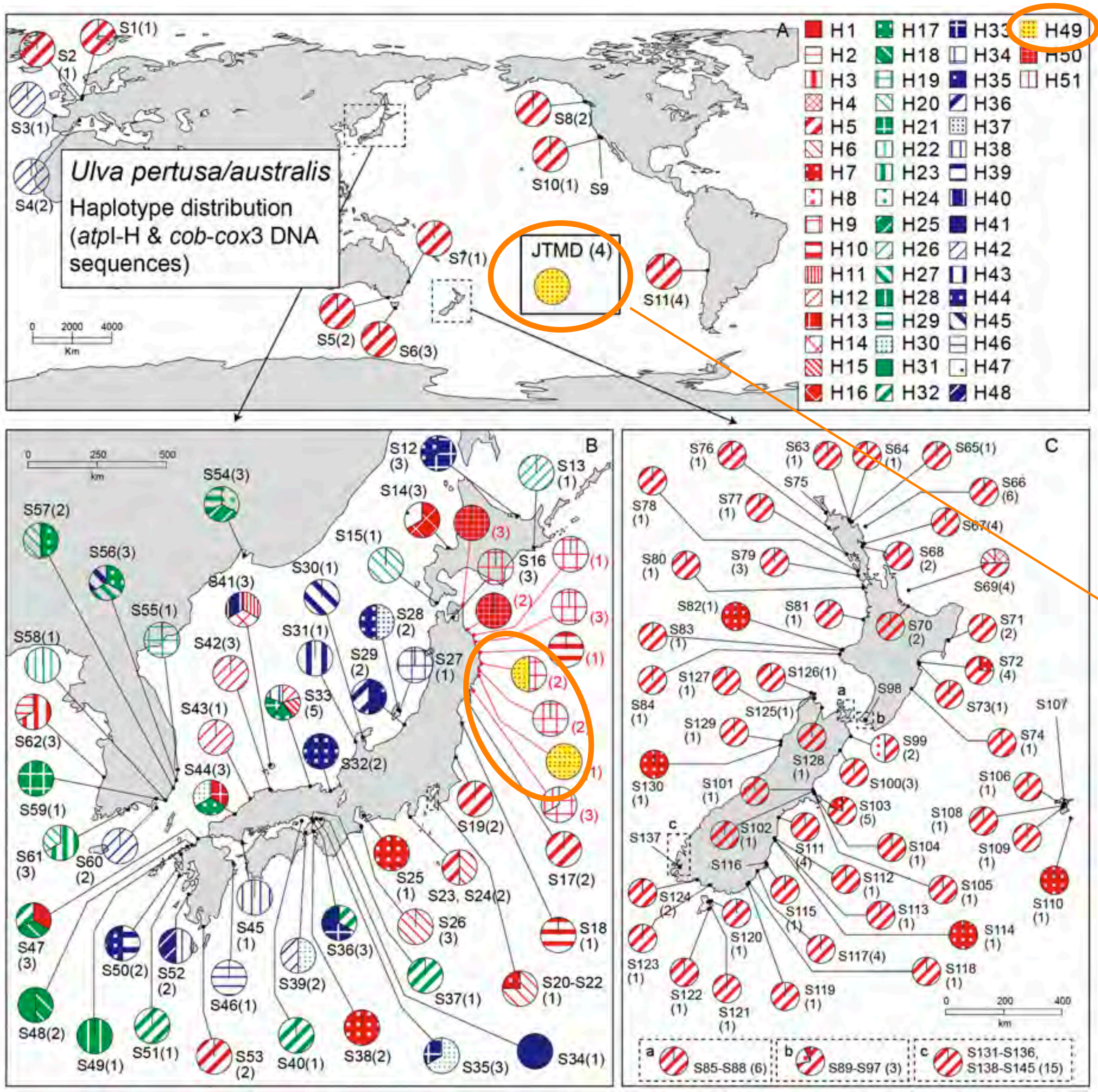
Gayle Hansen (Oregon State University)




Diversity of JTMD-Algae (macrophytes)

緑藻アナアオサの各地域集団の遺伝的多様性の解析

漂着した船名不詳の破損した漁船は東北沿岸に由来することが確かめられた

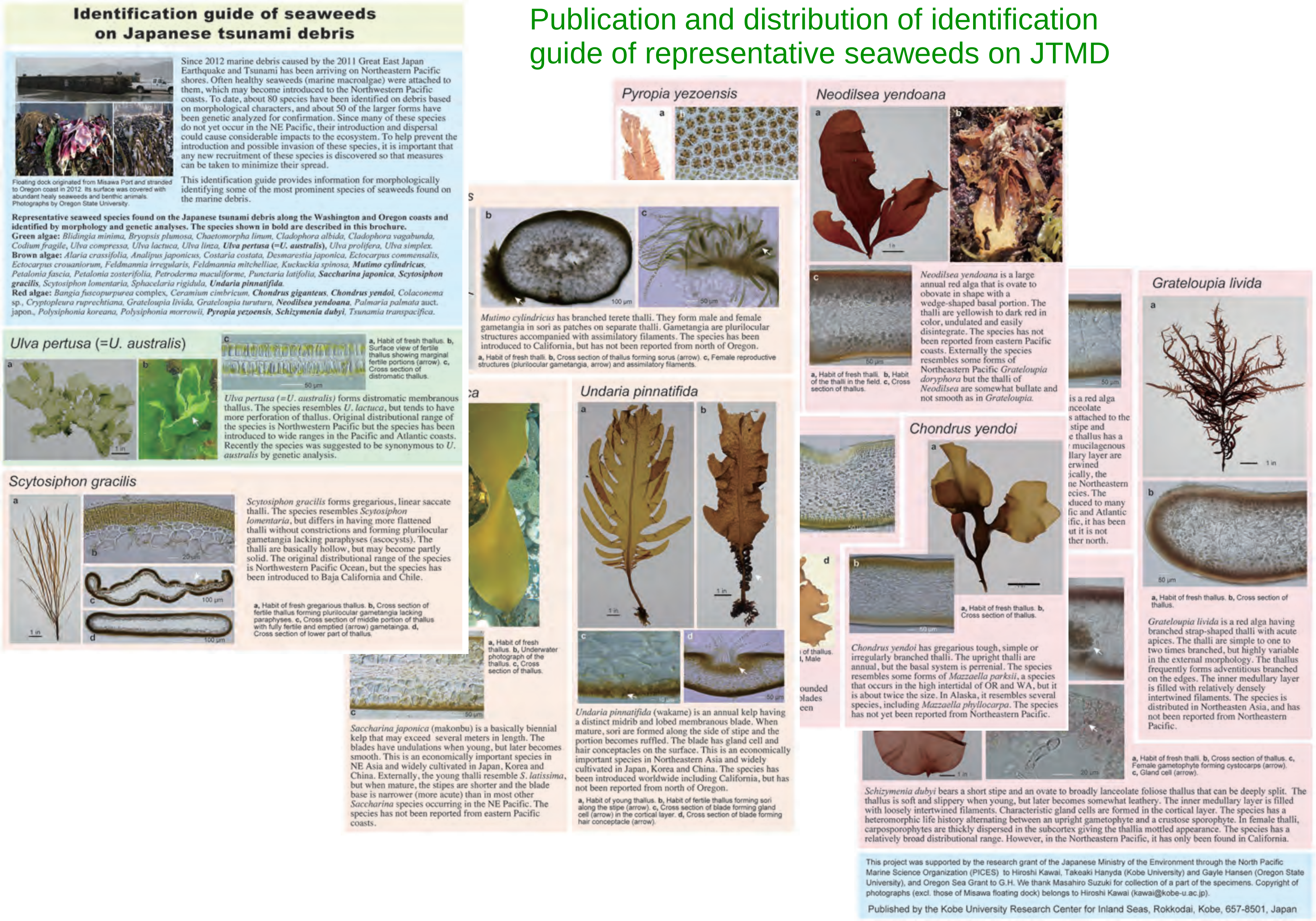


Origin of an anonymous boat carrying yellowtail jacks and banded knifejaw fish was confirmed to be originated from Tohoku region by the genetic type of the associated Ulva species.

Haplotypes based on mitochondrial *atp*I-H & *cob-cox3* gene DNA sequence

代表的な津波漂流物付着海藻の同定のためのパンフレットの作成・配付

Publication and distribution of identification guide of representative seaweeds on JTMD



Identification guide of seaweeds on Japanese tsunami debris

Since 2012 marine debris caused by the 2011 Great East Japan Earthquake and Tsunami has been arriving on Northeastern Pacific shores. Often healthy seaweeds (marine macroalgae) were attached to them, which may become introduced to the Northwestern Pacific coasts. To date, about 80 species have been identified on debris based on morphological characters, and about 50 of the larger forms have been genetic analyzed for confirmation. Since many of these species do not yet occur in the NE Pacific, their introduction and dispersal could cause considerable impacts to the ecosystem. To help prevent the introduction and possible invasion of these species, it is important that any new recruitment of these species is discovered so that measures can be taken to minimize their spread.

This identification guide provides information for morphologically identifying some of the most prominent species of seaweeds found on the marine debris.

Floating dock originated from Misawa Port and stranded to Oregon coast in 2012. Its surface was covered with abundant healy seaweeds and benthic animals. Photographs by Oregon State University.

Representative seaweed species found on the Japanese tsunami debris along the Washington and Oregon coasts and identified by morphology and genetic analyses. The species shown in bold are described in this brochure.

Green algae: *Blidingia minima, Bryopsis plumosa, Chaetomorpha linum, Cladophora albida, Cladophora vagabunda, Codium fragile, Ulva compressa, Ulva lactuca, Ulva linza,* ***Ulva pertusa (=U. australis)****, Ulva prolifera, Ulva simplex.*

Brown algae: *Alaria crassifolia, Analipus japonicus, Costaria costata, Desmarestia japonica, Ectocarpus commensalis, Ectocarpus crouaniorum, Feldmannia irregularis, Feldmannia mitchelliae, Kuckuckia spinosa,* ***Mutimo cylindricus****, Petalonia fascia, Petalonia zosterifolia, Petroderma maculiforme, Punctaria latifolia,* ***Saccharina japonica, Scytosiphon gracilis****, Scytosiphon lomentaria, Sphacelaria rigidula,* ***Undaria pinnatifida****.*

Red algae: *Bangia fuscopurpurea complex, Ceramium cimbricum,* ***Chondrus giganteus, Chondrus yendoi****, Colaconema sp., Cryptopleura ruprechtiana, Grateloupia livida, Grateloupia turuturu,* ***Neodilsea yendoana****, Palmaria palmata auct. japon., Polysiphonia koreana, Polysiphonia morrowii,* ***Pyropia yezoensis, Schizymenia dubyi****, Tsunamia transpacifica.*

Ulva pertusa (=U. australis)

a, Habit of fresh thallus. b, Surface view of fertile thallus showing marginal fertile portions (arrow). c, Cross section of distromatic thallus.

Ulva pertusa (=U. australis) forms distromatic membranous thallus. The species resembles *U. lactuca*, but tends to have more perforation of thallus. Original distributional range of the species is Northwestern Pacific but the species has been introduced to wide ranges in the Pacific and Atlantic coasts. Recently the species was suggested to be synonymous to *U. australis* by genetic analysis.

Scytosiphon gracilis

Scytosiphon gracilis forms gregarious, linear saccate thalli. The species resembles *Scytosiphon lomentaria*, but differs in having more flattened thalli without constrictions and forming plurilocular gametangia lacking paraphyses (ascocysts). The thalli are basically hollow, but may become partly solid. The original distributional range of the species is Northwestern Pacific Ocean, but the species has been introduced to Baja California and Chile.

a, Habit of fresh gregarious thallus. b, Cross section of fertile thallus forming plurilocular gametangia lacking paraphyses. c, Cross section of middle portion of thallus with fully fertile and emptied (arrow) gametanga. d, Cross section of lower part of thallus.

Pyropia yezoensis

Neodilsea yendoana

Neodilsea yendoana is a large annual red alga that is ovate to obovate in shape with a wedge-shaped basal portion. The thalli are yellowish to dark red in color, undulated and easily disintegrate. The species has not been reported from eastern Pacific coasts. Externally the species resembles some forms of Northeastern Pacific *Grateloupia doryphora* but the thalli of *Neodilsea* are somewhat bullate and not smooth as in *Grateloupia*.

a, Habit of fresh thalli. b, Habit of the thalli in the field. c, Cross section of thallus.

Mutimo cylindricus has branched terete thalli. They form male and female gametangia in sori as patches on separate thalli. Gametangia are plurilocular structures accompanied with assimilatory filaments. The species has been introduced to California, but has not been reported from north of Oregon.

a, Habit of fresh thalli. b, Cross section of thallus forming sorus (arrow). c, Female reproductive structures (plurilocular gametangia, arrow) and assimilatory filaments.

Grateloupia livida

a, Habit of fresh thallus. b, Cross section of thallus.

Grateloupia livida is a red alga having branched strap-shaped thalli with acute apices. The thalli are simple to one to two times branched, but highly variable in the external morphology. The thallus frequently forms adventitious branched on the edges. The inner medullary layer is filled with relatively densely intertwined filaments. The species is distributed in Northeasten Asia, and has not been reported from Northeastern Pacific.

Chondrus yendoi

a, Habit of fresh thallus. b, Cross section of thallus.

Chondrus yendoi has gregarious tough, simple or irregularly branched thalli. The upright thalli are annual, but the basal system is perennial. The species resembles some forms of *Mazzaella parksii*, a species that occurs in the high intertidal of OR and WA, but it is about twice the size. In Alaska, it resembles several species, including *Mazzaella phyllocarpa*. The species has not yet been reported from Northeastern Pacific.

Undaria pinnatifida

Undaria pinnatifida (wakame) is an annual kelp having a distinct midrib and lobed membranous blade. When mature, sori are formed along the side of stipe and the portion becomes ruffled. The blade has gland cell and hair concepta cles on the surface. This is an economically important species in Northeastern Asia and widely cultivated in Japan, Korea and China. The species has been introduced worldwide including California, but has not been reported from north of Oregon.

a, Habit of young thallus. b, Habit of fertile thallus forming sori along the stipe (arrow). c, Cross section of blade forming gland cell (arrow) in the cortical layer. d, Cross section of blade forming hair conceptacle (arrow).

a, Habit of fresh thallus. b, Underwater photograph of the thallus. c, Cross section of thallus.

Saccharina japonica (makonbu) is a basically biennial kelp that may exceed several meters in length. The blades have undulations when young, but later becomes smooth. This is an economically important species in NE Asia and widely cultivated in Japan, Korea and China. Externally, the young thalli resemble *S. latissima*, but when mature, the stipes are shorter and the blade base is narrower (more acute) than in most other *Saccharina* species occurring in the NE Pacific. The species has not been reported from eastern Pacific coasts.

a, Habit of fresh thalli. b, Cross section of thallus. c, Female gametophyte forming cystocarps (arrow). c, Gland cell (arrow).

Schizymenia dubyi bears a short stipe and an ovate to broadly lanceolate foliose thallus that can be deeply split. The thallus is soft and slippery when young, but later becomes somewhat leathery. The inner medullary layer is filled with loosely intertwined filaments. Characteristic gland cells are formed in the cortical layer. The species has a heteromorphic life history alternating between an upright gametophyte and a crustose sporophyte. In female thalli, carposporophytes are thickly dispersed in the subcortex giving the thallia mottled appearance. The species has a relatively broad distributional range. However, in the Northeastern Pacific, it has only been found in California.

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Species Risk Assessment
種としての津波海洋漂流物付着生物種のリスクアセスメント

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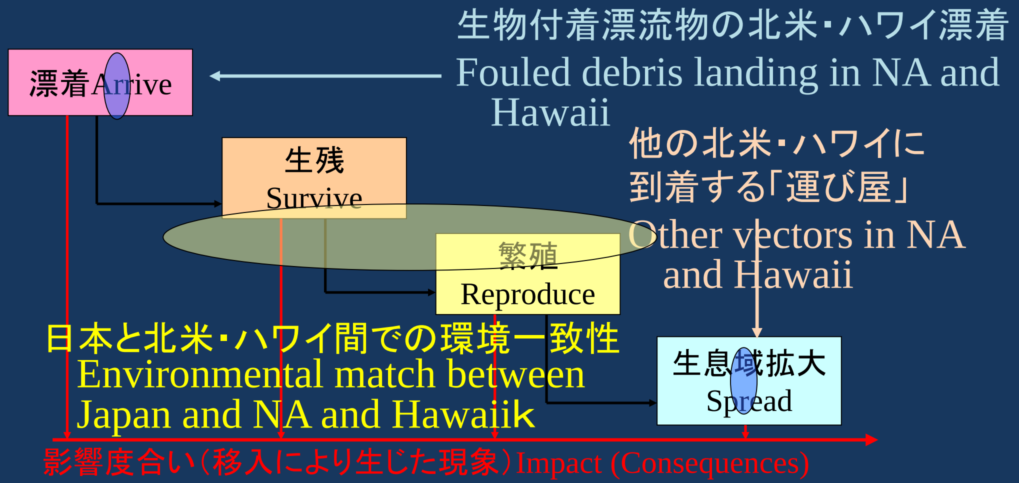
PICES

Williams

Fisheries and Oceans Canada | Pêches et Océans Canada

津波海洋漂流物を対象にした評価方法
So for Japanese Tsunami Debris

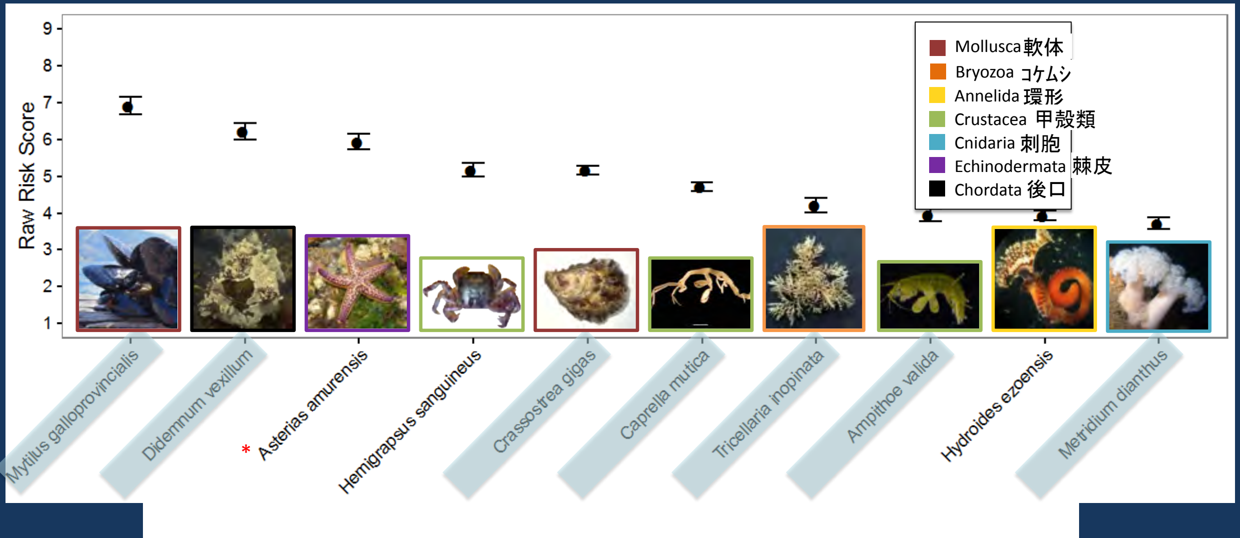


カナダ海洋移入種選別ツール
Canadian Marine Invasive Screening Tool (CMIST)

- 移入可能性とその影響に関するリスク評価のための選別ツール
  Screening tool that evaluates risk based on invasion likelihood and impacts
- 17個の質問で三段階にランク付けを行う。
  17 Questions scored from low (1) to high risk (3):
  - 現在の状況　Present status in the area
  - 導入される割合・速度　Rate of introduction
  - 生存　Survival
  - 生息の確立　Establishment
  - 拡大　Spread
  - 影響　Impact
- 評価者による不確実性を評価する
- Captures assessor uncertainty
- 漂流物に見つかった132種の無脊椎動物について評価を試みた
  We applied to 132 invertebrates on debris

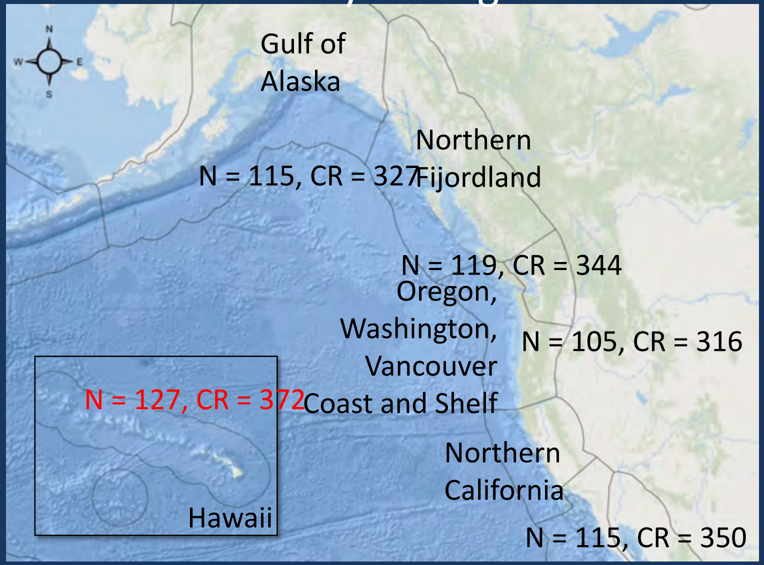
CSAS Science Advisory Report 2015/04
Drolet et al. (2016) Biological Invasions 18

多くのものは既に北米西海岸やハワイに移入している
Many of these are already present



Photos from iucngisd.org, cabi.org, invasions.si.edu, marlin.ac.uk, and Kishikawa (2011)

生態区分（エコリージョン）毎のリスク評価
Risk by Ecoregion

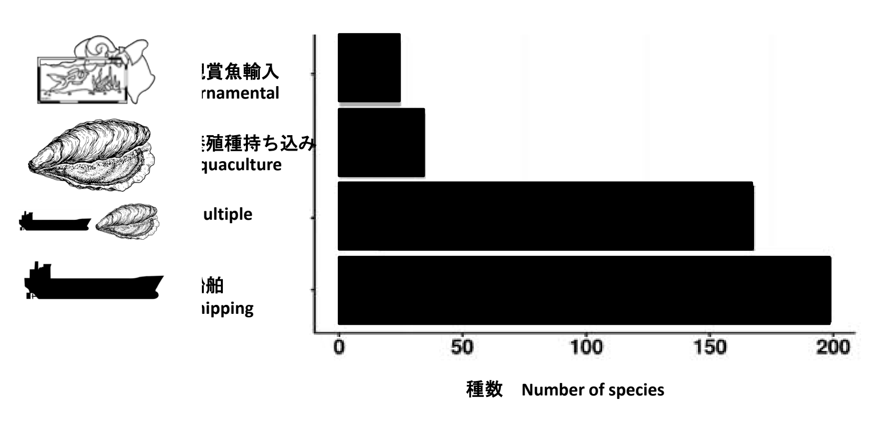


Spalding et al. (2007) BioScience 57 (7)

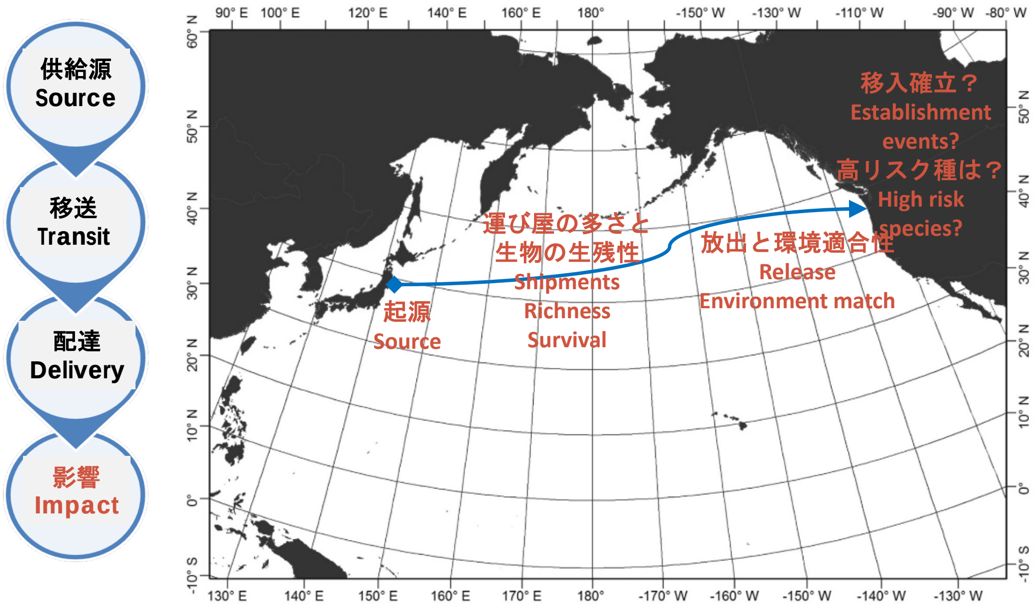
移入種の“運び屋”（ベクター）としての津波漂流物のリスクアセスメント VECTOR RISK ASSESSMENT: HOW DOES TSUNAMI DEBRIS COMPARE?

Dr. Cathryn Clarke Murray
PICES Project Scientist (presently, DFO)

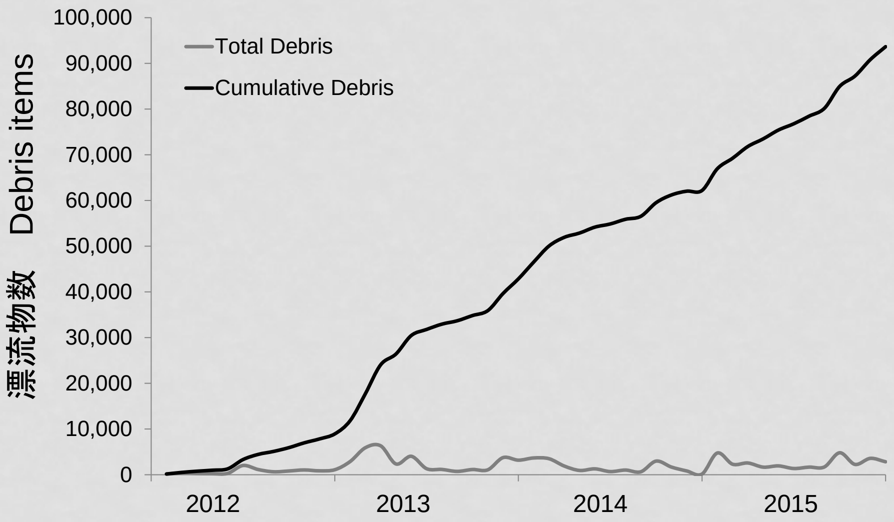
200種以上の生物が既に他の経済行為により導入されている。 MORE THAN 200 SPECIES HAVE ALREADY BEEN INTRODUCED BY OTHER ACTIVITIES



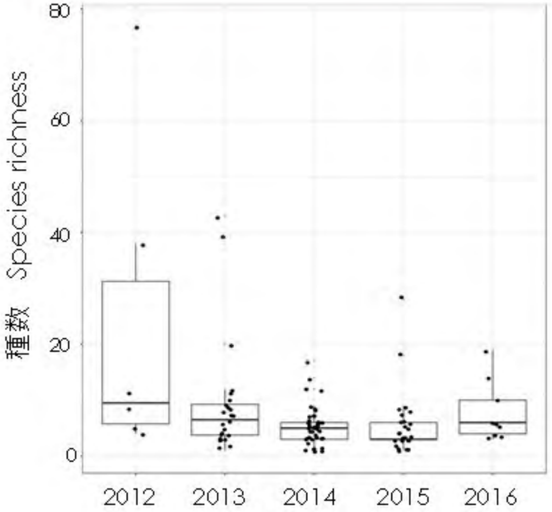
移入過程　THE INVASION PROCESS



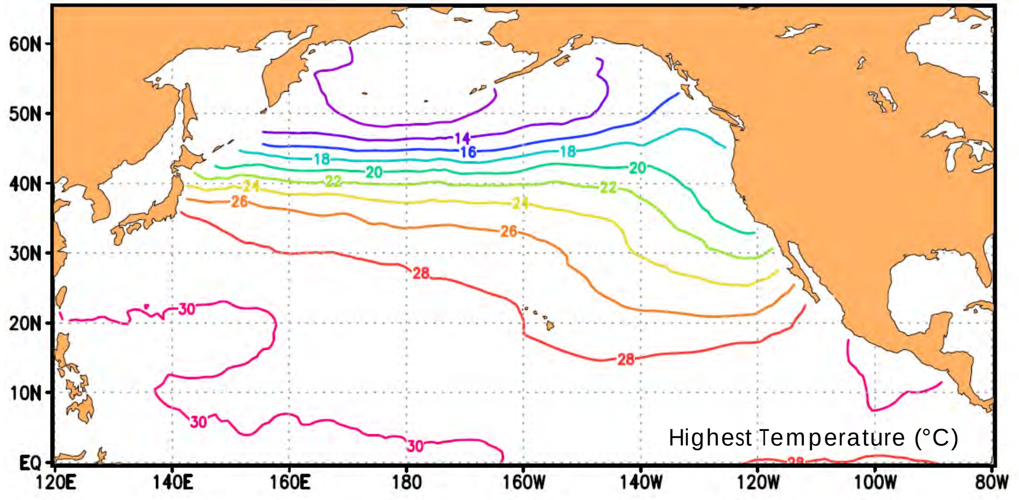
移送　TRANSIT – 津波漂流物数　NUMBER OF ITEMS

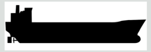
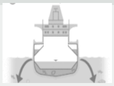


移送 TRANSIT – 漂流物当たりの種数 RICHNESS PER ITEM



運搬 DELIVERY –環境適合性 ENVIRONMENTAL MATCH
例： 北太平洋における年間最高表面海水温度の分布

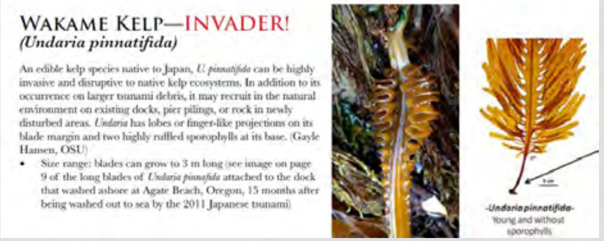


運び屋 VECTOR	起源 SOURCE	移送 TRANSIT			運搬 DELIVERY	
	供給源量 Source	種数 Richness	数量 Number	生残 Survival	放出 Release	環境適合性 Environment Match
津波漂流物 Tsunami Debris	O	◦	O	o	O	o
 船体付着 Hull fouling	O	o	O	o	O	o
 バラスト水 Ballast Water	O	O	O	o	o	o
 観賞魚輸入 Ornamental	O	O	O	O	◦	◦
 養殖種の輸入 Aquaculture	O	◦	◦	O	O	O

津波漂流物は比較的低リスクと考えられる。
JTMD COMPARATIVELY LOWER RISK

しかしながら、高リスク種の導入可能性から今後の監視が必要である。。。

However... potential to introduce high risk species will require monitoring



WAKAME KELP—INVADER!
(Undaria pinnatifida)

An edible kelp species native to Japan, *U. pinnatifida* can be highly invasive and disruptive to native kelp ecosystems. In addition to its occurrence on larger tsunami debris, it may recruit in the natural environment on existing docks, pier pilings, or rock in newly disturbed areas. *Undaria* has lobes or finger-like projections on its blade margin and two highly ruffled sporophylls at its base. (Gayle Hansen, OSU)

- Size range: blades can grow to 3 m long (see image on page 9 of the long blades of *Undaria pinnafida* attached to the dock that washed ashore at Agate Beach, Oregon, 15 months after being washed out to sea by the 2011 Japanese tsunami)

-*Undaria pinnatifida*-
Young and without sporophylls

NORTHERN PACIFIC SEASTAR—INVADER!
(Asterias amurensis)

This species of sea star is predominantly light purple in color, and is often seen with purple or red detail on its upper surface. There are numerous small spines with sharp edges on the upper body surface. On the underside of the body, these spines line the groove in which the tube feet lie, and join up at the mouth in a fan-like shape. The underside is a uniform yellow in color. It is normally found in shallow water, but it can also be found from the intertidal area through to the subtidal as deep as 200 m. (New Zealand Ministry for Primary Industries)

- Size range: can reach 40 to 50 cm in diameter

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プロジェクト課題担当機関 ~ 15 organizations

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  オレゴン州立大学
  ハットフィールド海洋科学センター
- Moss Landing Marine Laboratory
  モスランディング海洋研究所
- Smithsonian Environmental Research Center
  スミソニアン環境研究センター
- International Pacific Research Center (IPRC),
  University of Hawaii
  ハワイ大学，国際太平洋研究センター
- Williams College and Mystic Seaport
  ウィリアムズ大学&ミスティック海港博物館

- Ehime University 愛媛大学
- Kagoshima University 鹿児島大学
- Kobe University 神戸大学
- Kyushu University 九州大学
- Tokyo University of Science 東京理科大学
- Meteorological Research Institute,
  Japan Meteorological Agency 気象研
- Japan Agency for Marine-Earth Science Technology (JAMSTEC)
  海洋研究開発機構
- National Institute for Land and Infrastructure Management
  国土技術政策総合研究所
- Fisheries Research Agency 水産研究機構
- JANUS 日本エヌ・ユー・エス

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- Nancy Treneman, USA
- Cathryn Murray, Canada


2016.11.10

OUTCOMES AND LEGACY PRODUCTS

- Hawaiian Islands Marine Debris Aerial Imagery Surveys (2015–2016)
- Webcam monitoring of marine/tsunami debris (2014–2017)
- Development of life history database for Japanese Tsunami Marine Debris (JTMD) biota (2015–2016)
- Japan Tsunami Debris species database (2012-2017)
- British Columbia (BC) Coast Marine Debris Aerial Imagery Surveys
- Special Issues of ‘Aquatic Invasions’ and ‘Marine Pollution Bulletin’