2017.5.18. Tokyo

漂着物付着生物の多様性 – 海藻 –

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Species and genetic diversity of seaweeds on Japanese tsunami debris

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Gayle Hansen (Oregon State University)

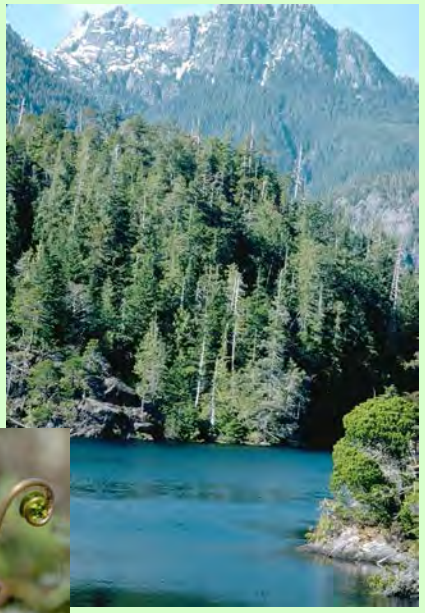


- 藻類，海藻類はどのような生き物？
- 津波漂流物付着海藻類の種多様性
- 津波漂流物付着海藻類の遺伝的多様性
- 海藻類移入の早期検出に向けて

- What are algae and seaweeds?
- Representative NIS seaweeds.
- How to elucidate their introduction origin and pathway.
- Potetial introductions by tsunami debris

Terrestrial ecosystem

陸域



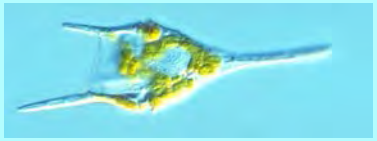
陸上植物　Land plants

沿岸 (浅い海)　Coastal zone

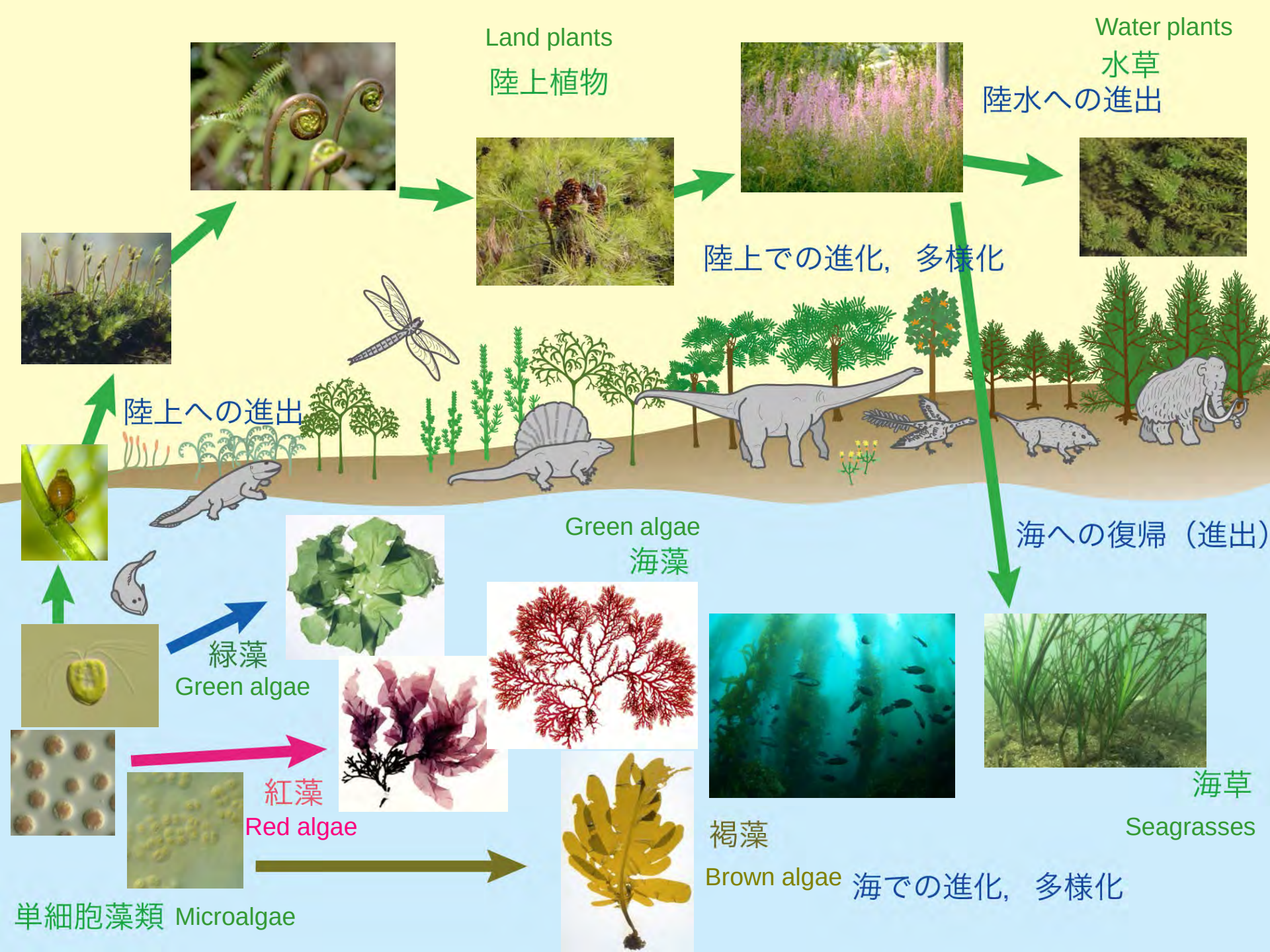
植物プランクトン・底生微細藻類

海藻・海草　Microalgae, macroalgae, seagrasses

外洋 (深い海)　Oceans

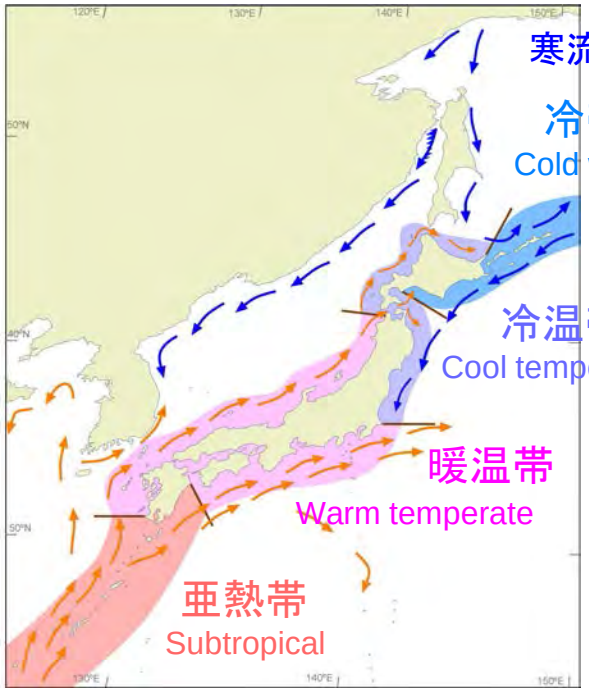


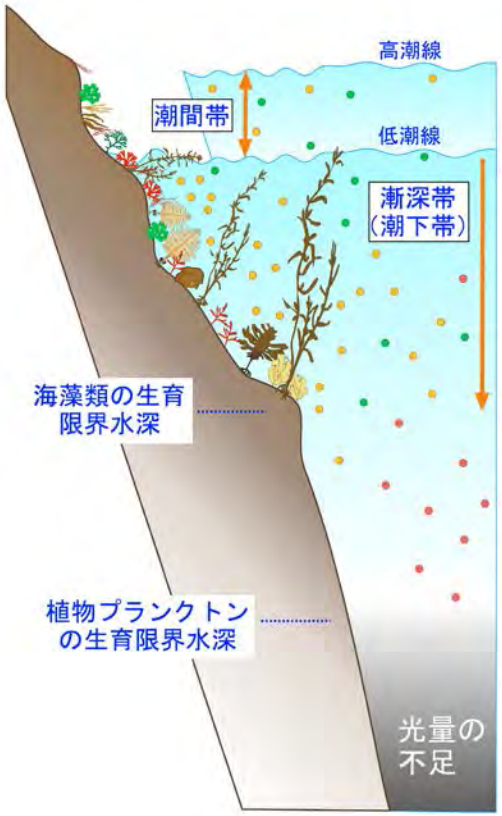
植物プランクトン　Phytoplankons


Land plants
陸上植物
Water plants
水草
陸水への進出
陸上での進化，多様化
陸上への進出
海への復帰（進出）
Green algae
海藻
緑藻
Green algae
紅藻
Red algae
褐藻
Brown algae
海草
Seagrasses
単細胞藻類 Microalgae
海での進化，多様化

- 海藻類の分布は水温（海流）の影響を強く受ける
- 光が届かない水深帯では生育できず，分布は広がりにくい
- それぞれの種類の分布域は温帯域では比較的狭い

- Distribution influenced by water tempreature and currents
- Max. depth of growth is 100-150m
- Relatively narrow distributional ranges

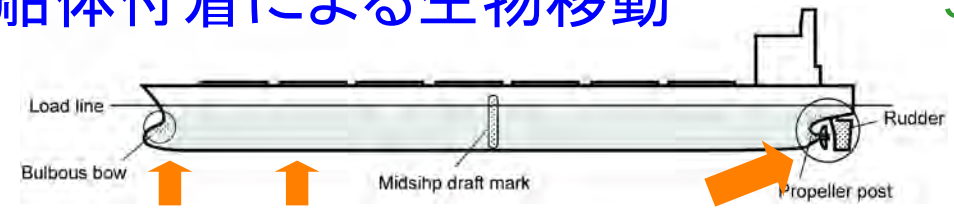




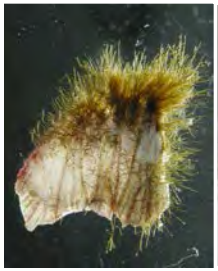
ワカメの自生域

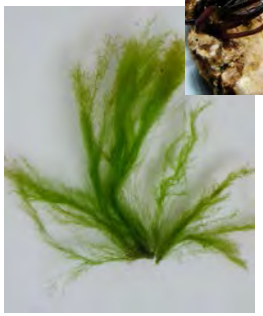
船体付着による生物移動

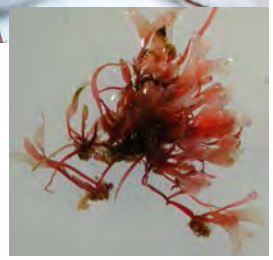
Ship hull carries benthic organisms







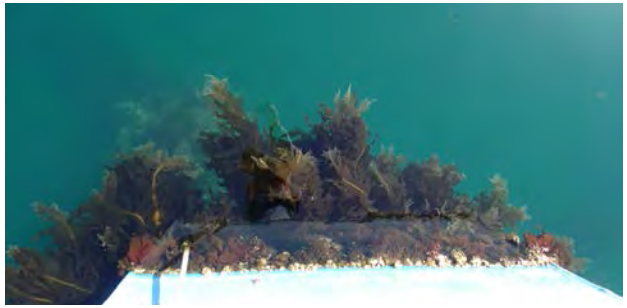
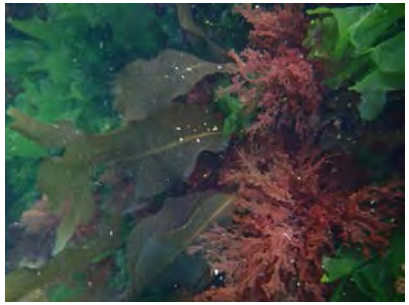




船体にはフジツボ類などの底生動物のほか海藻類も付着するが，その多くはアオサ類，シオミドロ類のように小形の種で，生育期間が短いものが多い

浮桟橋などに付着する海藻類

Floating dock has rich seaweed vegetation

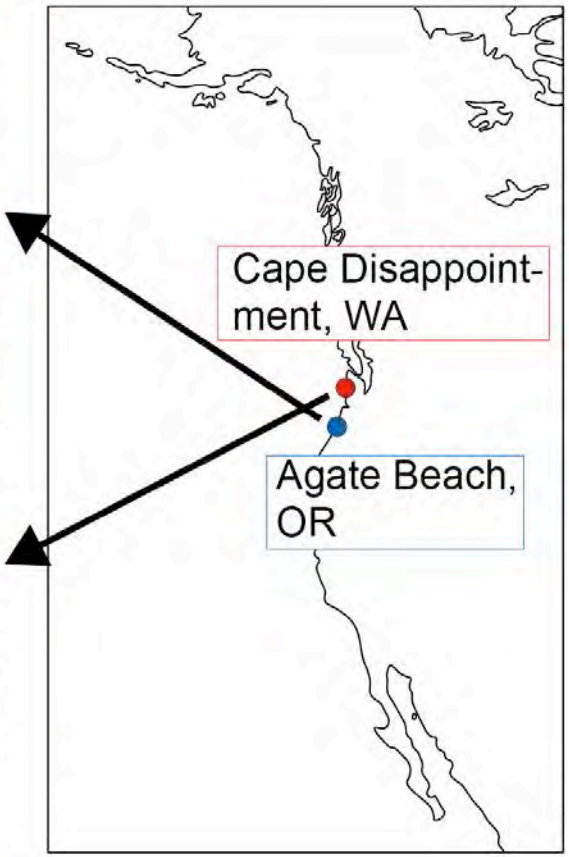

一般に浮き桟橋は，環境が安定しているため周辺の護岸より海藻類の種多様性が高く，通常はより深いところに生育する種も着生する

北米西海岸に漂着した震災津波漂流物

Tsunami debris stranded to Northwestern American coast

浮き桟橋（オレゴン州，2012年6月6日漂着）

漁船（ワシントン州，2012年6月16日漂着）



- 高い種多様性と現存量
- 一年生，多年生の種が健全に生育し，また成熟していた
- 異形の世代交代をする種が浮桟橋上で世代交代をしていた
- 海藻類だけではなく共存する動物も一緒に移動した

- High species diversity and biomass
- Not only annual but also perennial species were transported in healthy condition and were reproductive
- Species of heteromorphic life history have regenerated on the floating dock
- Animals associated with seaweeds have survived the transport

Marine Organisms Found Living on a Floating Dock from Misawa, Aomori Prefecture, Japan dislodged by the 2011 Tōhoku Earthquake and Tsunami

1 species of urchin

Northern Pacific seastar
Asterias amurensis

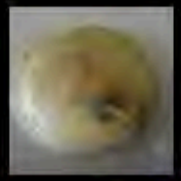
Japanese shore crab
Hemigrapsus sanguineus

4+ species of barnacle

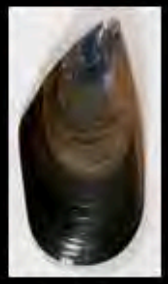
Solitary tunicate

Granular claw crab

Oedignathus inermis



Oyster



Mytilus galloprovincialis

Undaria pinnatifida

3+ species of amphipod

Bryozoans

Sponge on mussel

11 species of mollusk

Anemone

17+ species of worm

Halosydna brevisetosa

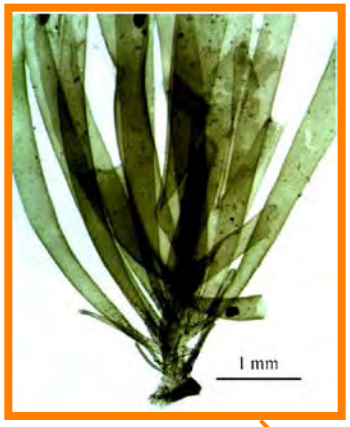
Trypanosyllis zebra

Oregon State University's Hatfield Marine Science Center & Coastal Oregon Marine Experiment Station

津波漂流物に付着していた海藻の多様性

緑藻　Green algae

アナアオサ



Ulva simplex

オオバアオサ

ウスバアオノリ

ヒメアオノリ

ワタシオグサ

北米西岸に本来分布しない種

ミル

ハネモ

褐藻　Brown algae

マコンブ

ワカメ

マツモ

カヤモノリ

ウスカヤモ

ケウルシグサ

ウルシグサ

ムチモ

セイヨウハバノリ

紅藻　Red algae

スサビノリ

ダルス

ベニスナゴ

アカバ

ヒラムカデ

オオバツノマタ

クロバギンナンソウ

ツルツル

東北沿岸，津波漂流物付着，北米西岸の海藻類集団の遺伝子比較

Comparisons of specimens from Tohoku region, JTMD and North America

漂流物付着藻類

Potential vectors (JTMD)

原産地自然集団

Original populations (donor)

Genetic comparisons

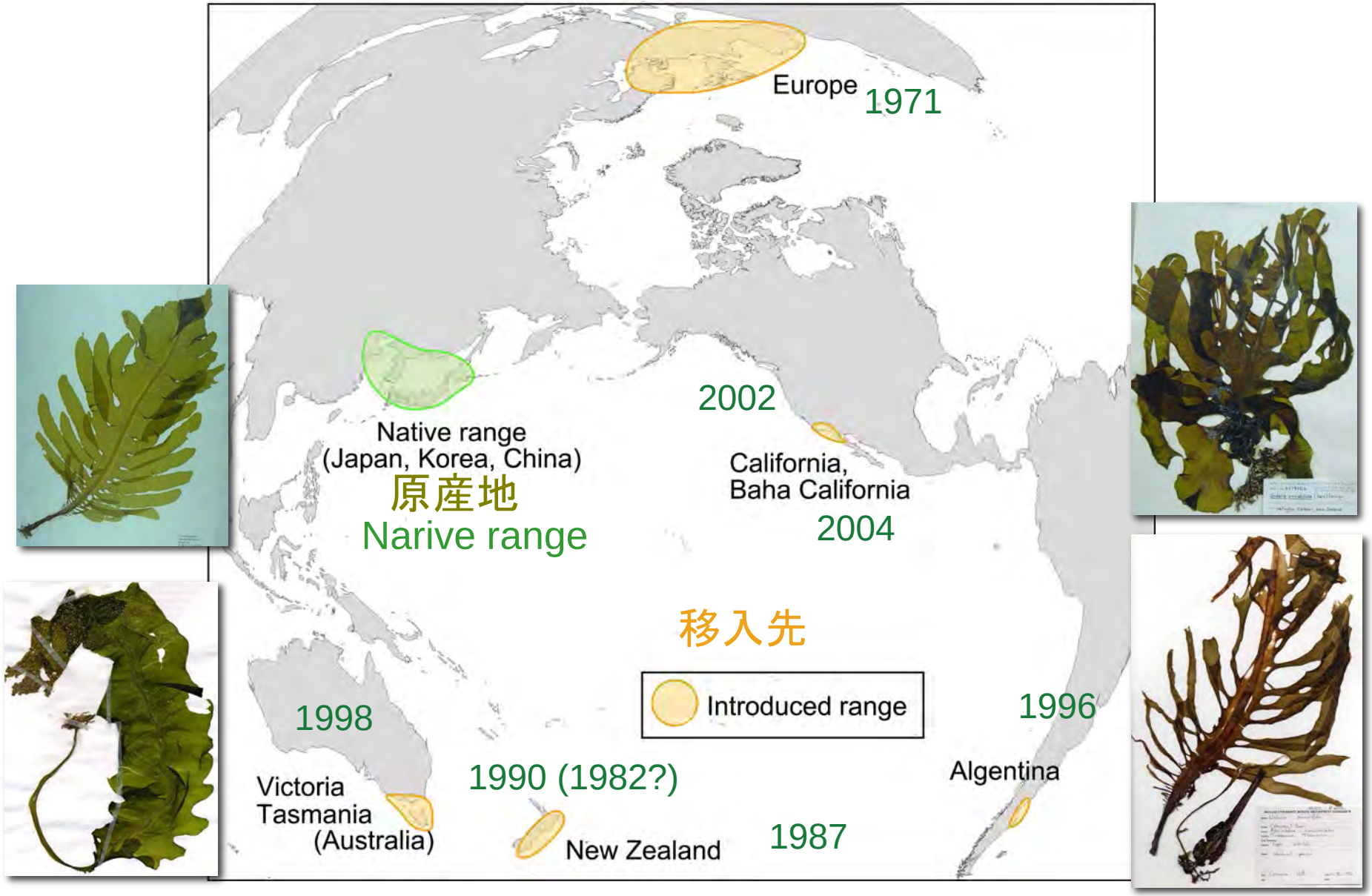
移入先自然･移入集団

Recipient populations

Native? Introduced?

世界各地でのワカメの分布と推定される移入時期

Worldwide distribution of *Undaria pinnatifida* and first records in the area



遺伝子による原産地集団の遺伝的多様性解析

cox 3 部分配列

cox 3 DNA sequence

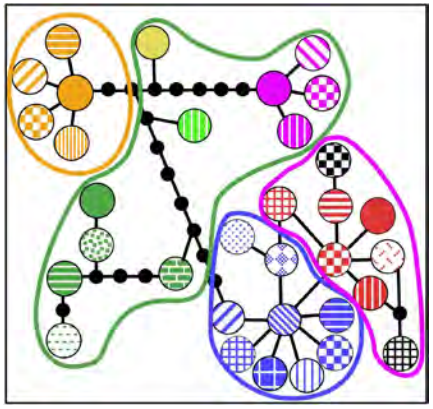
TACTTTTGCAGTTCAGCAAGGATTACGTATGGG
TATGATACTTTTTATTGTGTCTGAAATTATGTTTT
TTTTTGCTTTCTTTTGGGCTTTTTTTACTTCATC
GATATCCCCGTTTTTAATATTGGAGGTGTTT
GGCCTCCTGTAGGGATAGAAGCAATTAGCCC
ATGGGGATTACCTTTTTTAAATACTATTCTTTTA
CTTTCTTCAGGAGCAAGTGTTACATGGGCTCAT
CATGCAATTGTGGCTGGTTTTAAAAAAGAAGCT
TTACAAGGTTTAGGGGTAACATTAGGGTTTGCA
GTTGCGTTTACAGGTATGCAAGGTATTGAATAT
ATGCATGCTCCTTTTGGTATGTCAGATGGGGTT
TATGGTTCAGTATTTTATATGGCTACGGGATTT
CATGGATTTCATGTTATTATTGGAACAATATTCT
TAGCTATTTGTACAATAAGATTGTATTGGGACC
ATTTTA

ハプロタイプ番号

Number of haplotypes

1 -C-G-C-C-G-A-A-T-T-A-G-C-G-T-T-T-
2 -C-G-C-C-G-A-A-T-T-A-G-C-A-T-T-T-
3 -C-G-C-C-G-A-A-T-T-A-G-C-G-T-T-C-
4 -C-G-T-C-G-A-G-C-T-A-G-C-G-T-T-T-
5 -C-G-T-C-G-A-G-C-T-A-A-C-G-T-T-T-
6 -C-G-T-C-G-G-A-T-T-A-G-C-G-T-T-T-
7 -C-G-T-T-G-A-A-T-T-A-G-C-G-T-T-T-
8 -T-A-C-C-G-A-A-T-T-A-G-C-G-C-C-T-
9 -T-A-C-C-G-A-A-T-T-A-G-T-G-C-C-T-
10-T-G-C-T-G-A-A-T-C-A-G-C-G-T-T-T-
11-T-G-C-C-G-A-A-T-T-A-G-C-G-T-T-T-
12-T-G-C-C-G-A-A-T-T-G-G-C-G-T-T-T-
13-T-G-C-C-G-A-A-T-C-A-G-C-G-T-T-T-
14-C-G-C-C-A-A-A-T-T-A-G-C-G-T-T-T-

Genetic diversity of native population of *Undaria pinnatifida*

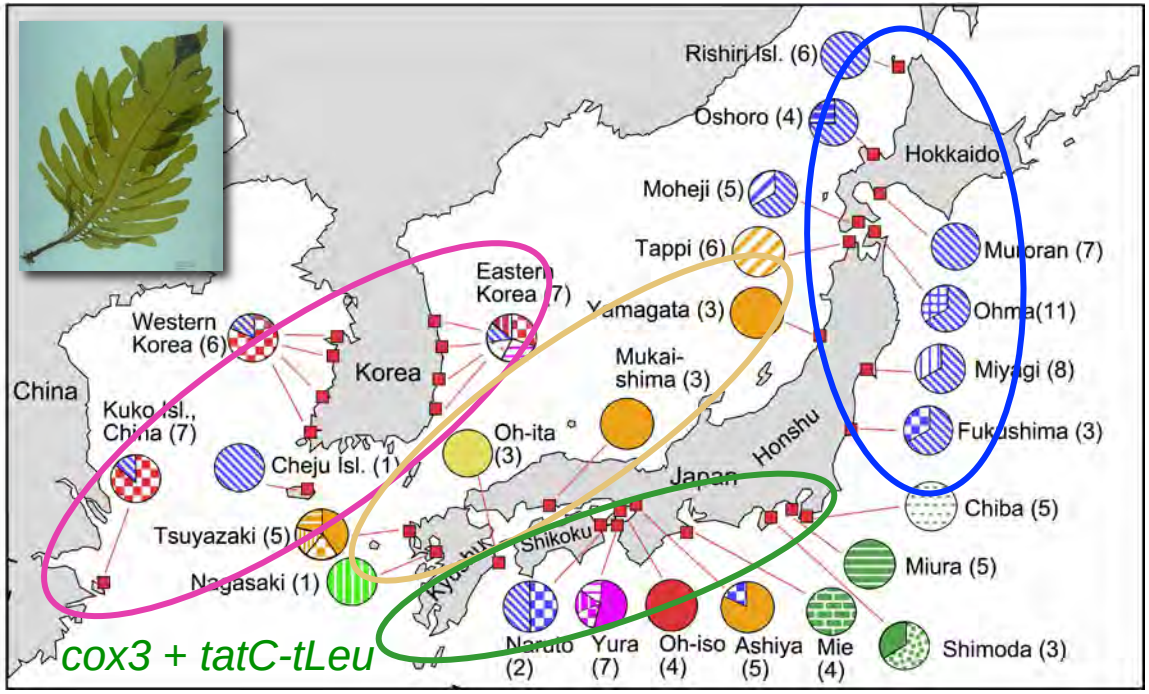


各ハプロタイプ（遺伝子型）間の遺伝的距離

Genetic relationship among haplotypes (spanning tree)

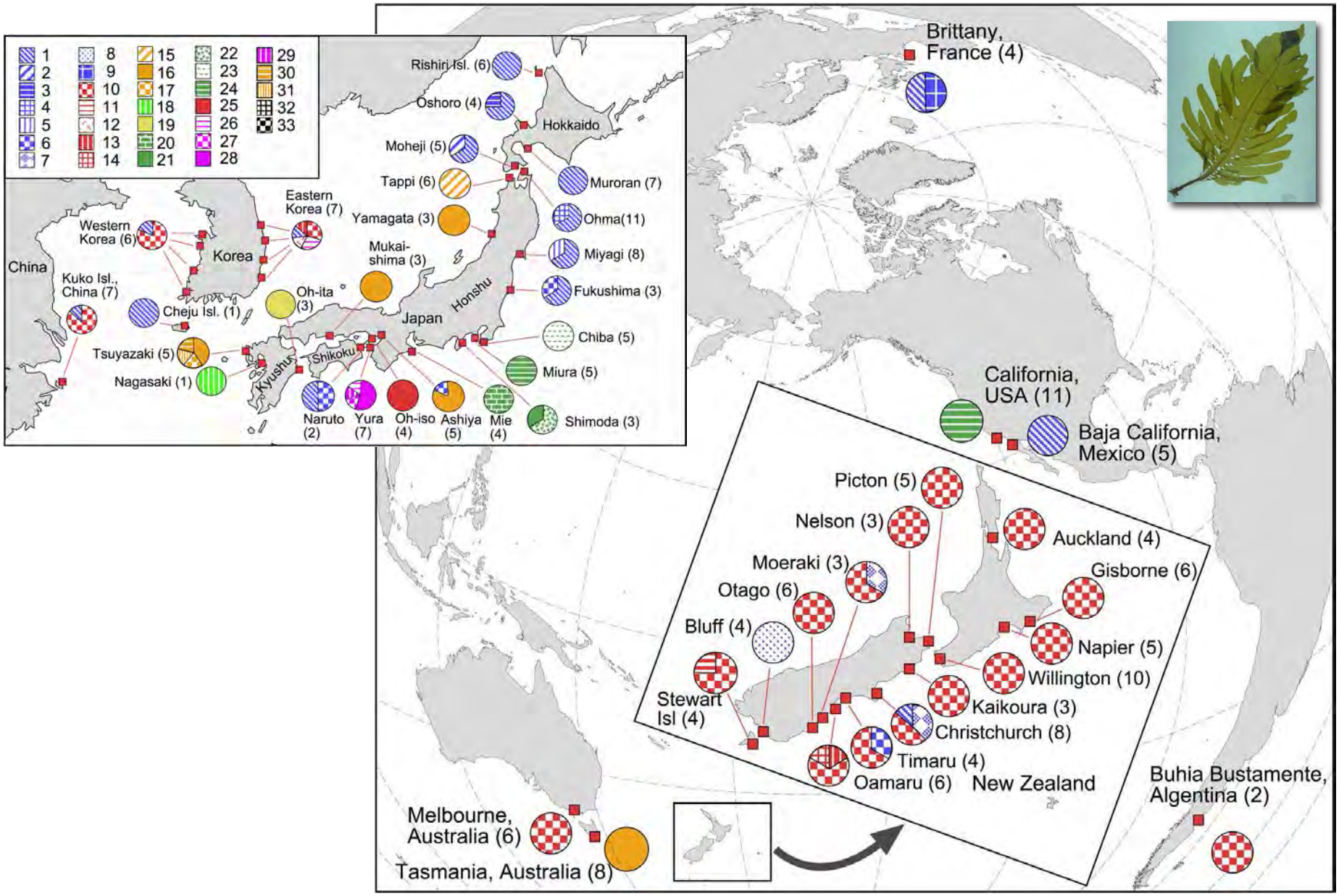
各地集団のハプロタイプ）`分布

Geographical distribution of haplotypes



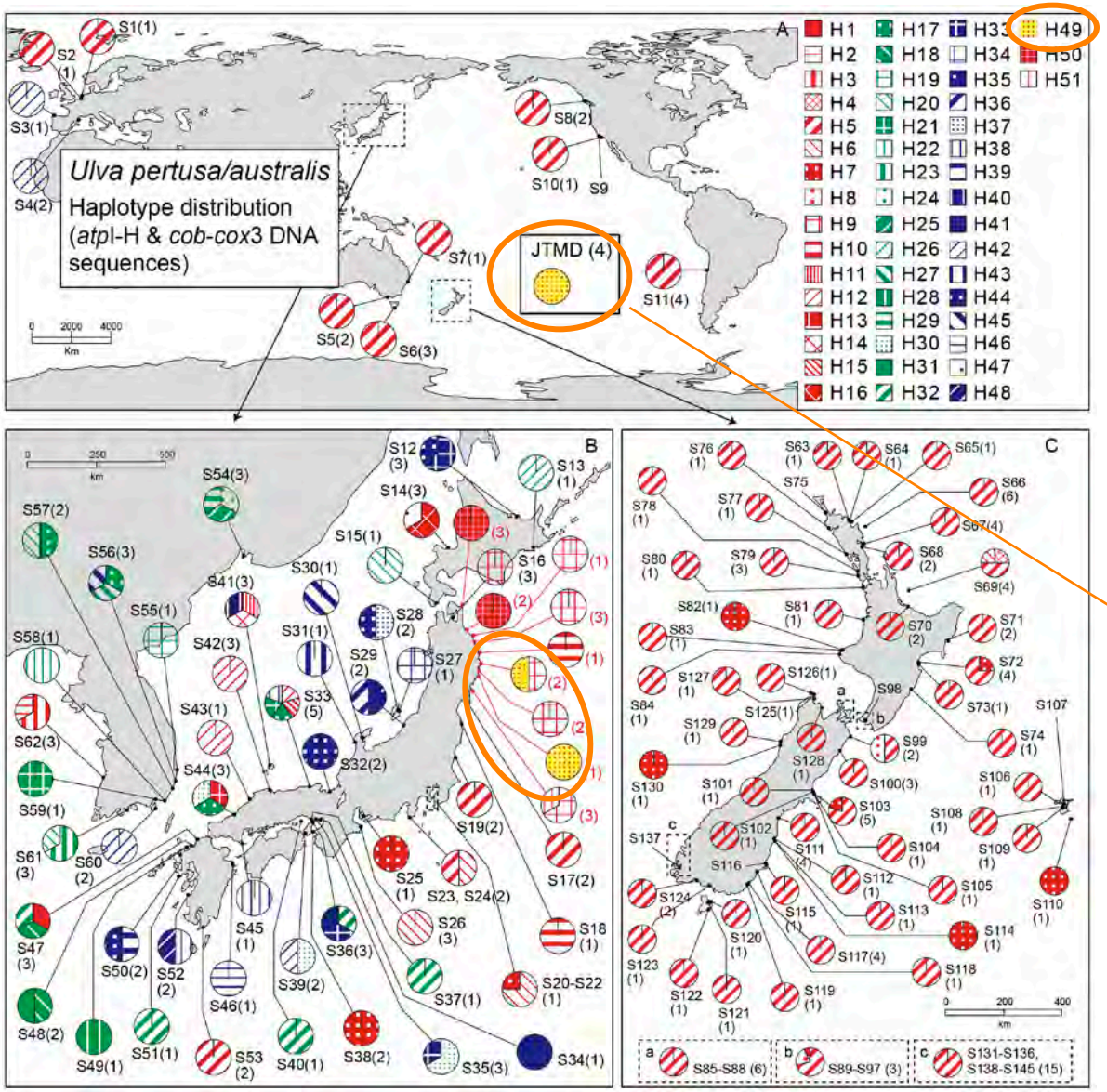
世界各地での各ハプロタイプの地理的分布

Worldwide geographical distribution of *cox3* + *tatC-tLeu* haplotypes



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



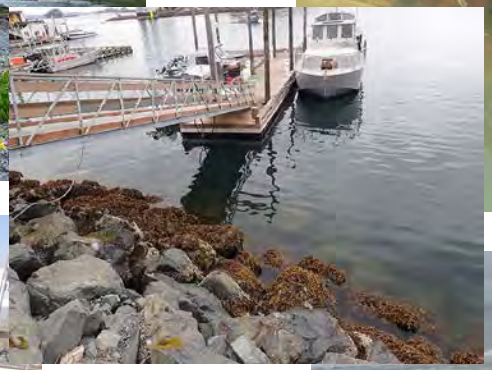
Origin of an anonymous boat carrying yellowtail jacks and banded knifejaw fish was confirmed to be originated from Tohoku region by the genetic type of the associated Ulva species.

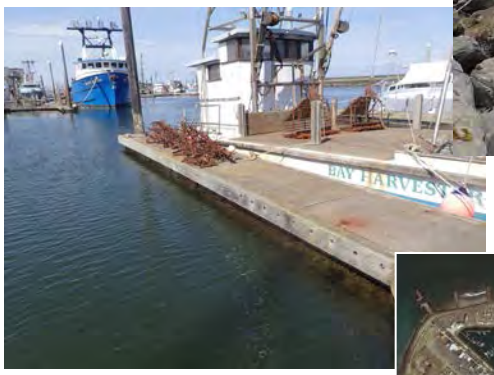
Haplotypes based on mitochondrial *atp*I-H & *cob-cox3* gene DNA sequence

移入海藻類の早期検出に向けて

さまざまな地点での野外調査

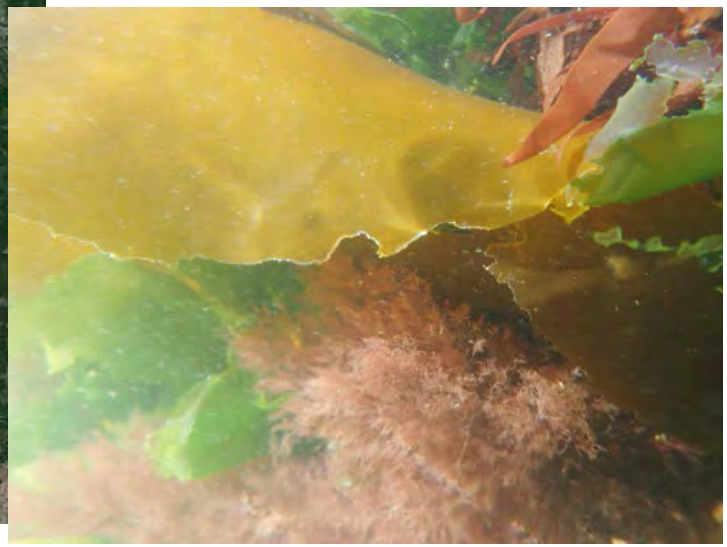
Field survey for detecting new recruitment

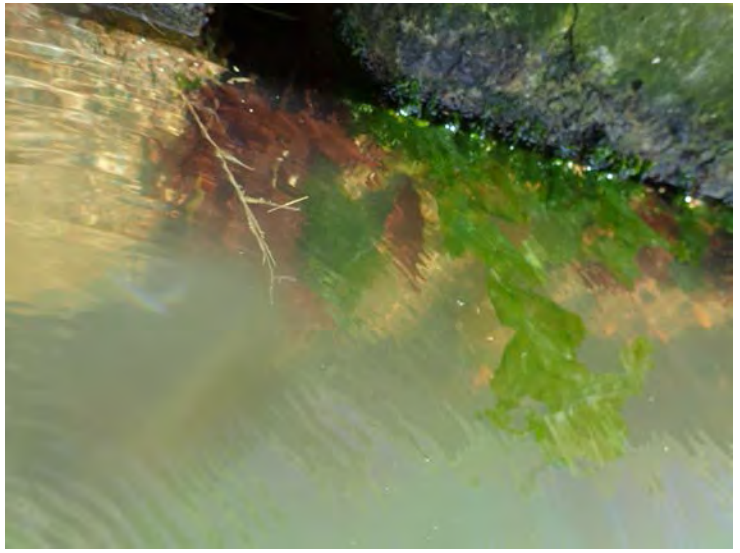




移入海藻類の早期検出に適した長期モニタリング場所の選定

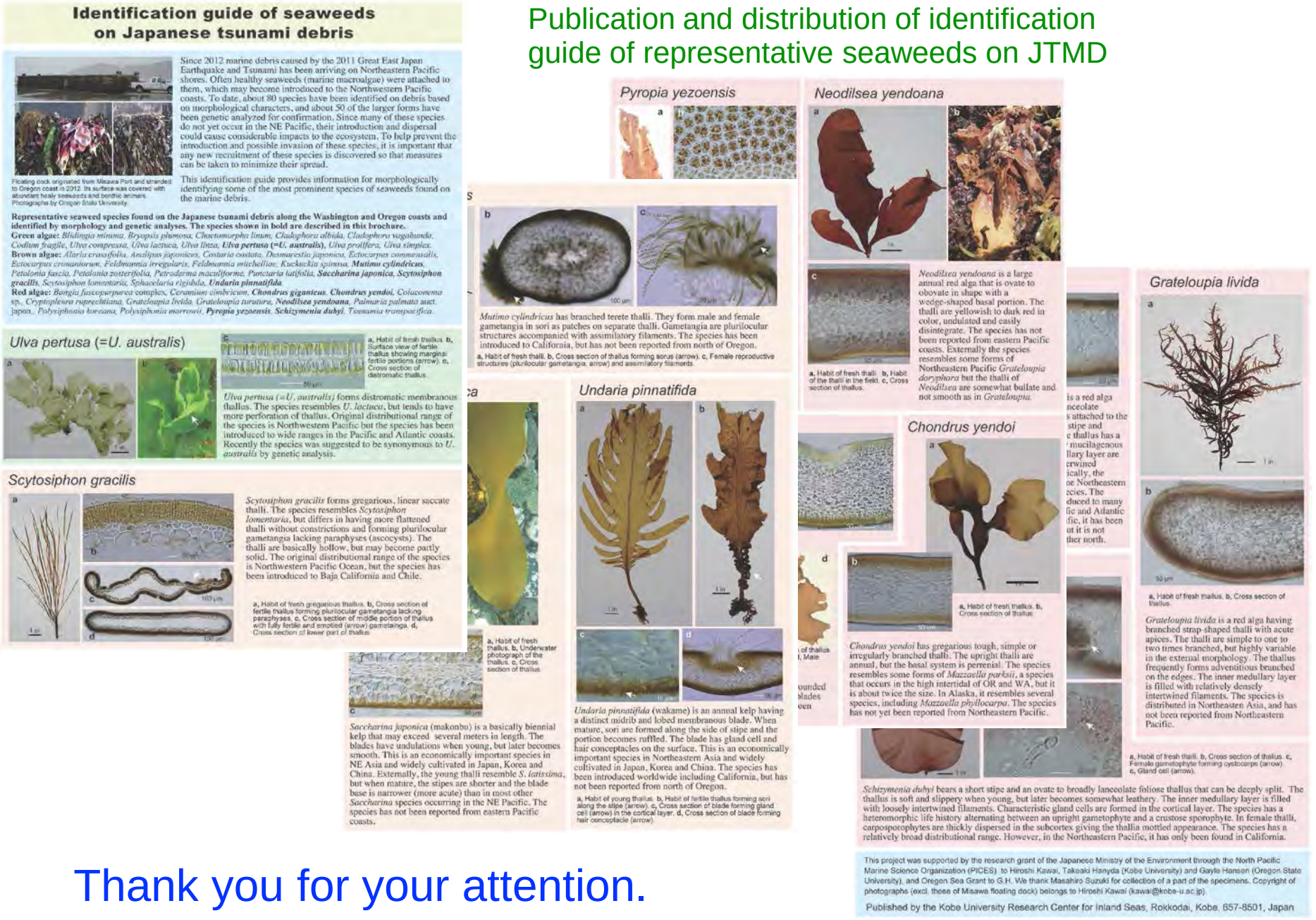
Selection of long-term monitoring sites for detecting new recruitment of JTMD algae





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.

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.

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

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, Petrodarma 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) gametangia. d, Cross section of lower part of thallus.

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.

Pyropia yezoensis

Mutimo cylindricus

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.

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 conceptacles 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).

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.

Chondrus yendoi

Chondrus yendoi has gregarious tough, simple or irregularly branched thalli. The upright thalli are annual, but the basal system is perrenial. 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.

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

Grateloupia livida

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 Northeastern Asia, and has not been reported from Northeastern Pacific.

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

Schizymenia dubyi

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.

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

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Thank you for your attention.