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# 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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- 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.
  - Potential introductions by tsunami debris



## Terrestrial ecosystem

### 陸域



### 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

### 陸上植物 Land plants

### 外洋 (深い海) Oceans



植物プランクトン Phytoplanktons



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



单細胞藻類 Microalgae



Green algae  
海藻



綠藻  
Green algae

紅藻  
Red algae



褐藻

海での進化、多様化

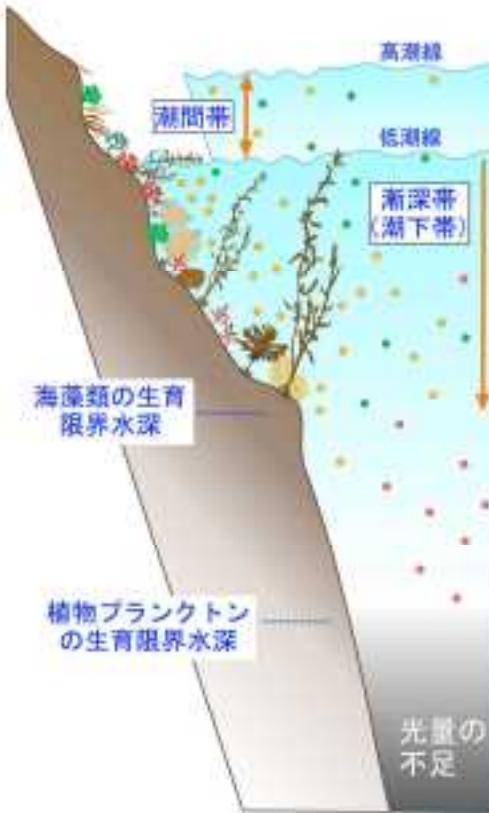
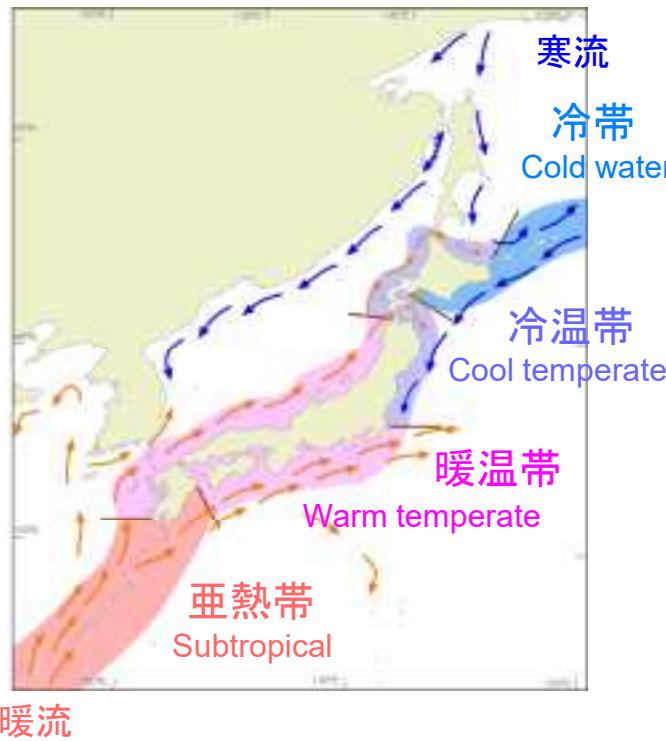


海草

Seagrasses

海への復帰（進出）

- 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 temperature 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

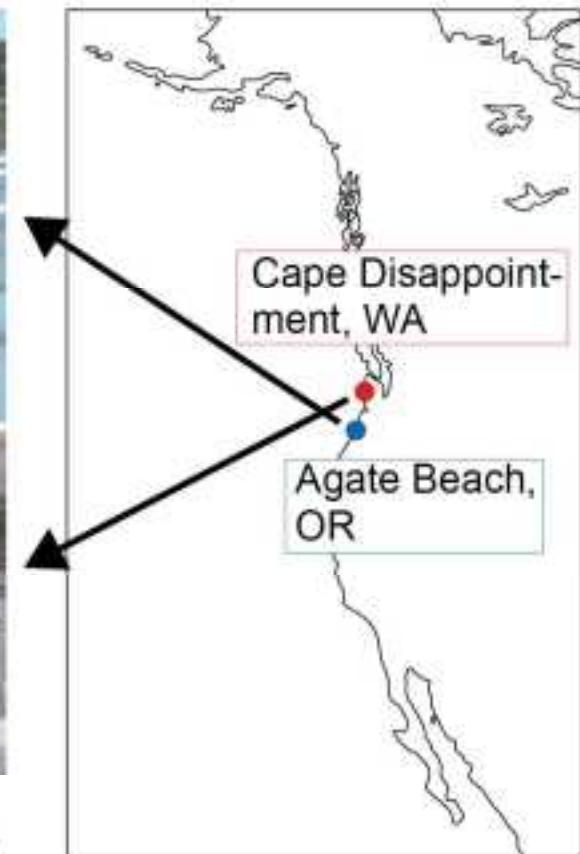
# 北米西海岸に漂着した震災津波漂流物

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)



WA, Mosquito Creek Dock  
3 Jan 2013

WA, Cape Disappointment Boat  
15 June 2012

OR, Salishan Boat  
6 Feb 2013

OR, Agate Beach Dock  
6 June 2012

- 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*



Granular claw crab



*Oedignathus inermis*



4+ species of barnacle

Bryozoans



3+ species of amphipod



*Undaria pinnatifida*



*Trypanosyllis zebra*

17+ species of worm



*Halosydna brevisetosa*



Oyster



*Mytilus galloprovincialis*



Sponge on mussel



11 species of mollusk



Anemone



# 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



ミル



ハネモ

北米西岸に本来分布しない種

# 褐藻

## Brown algae



マコンブ



ワカメ



マツモ



カヤモノリ



ウスカラヤモ



ケウルシグサ



ウルシグサ



ムチモ



セイヨウハバノリ  
3 cm

# 紅藻

## Red algae



スサビノリ



ダルス



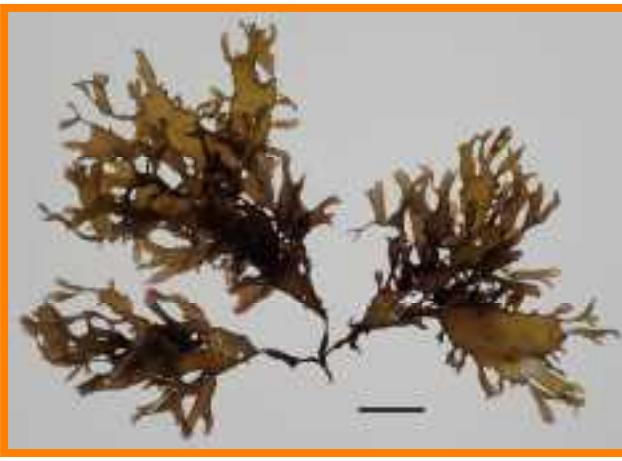
ベニスナゴ



アカバ



ヒラムカデ



オオバツノマタ



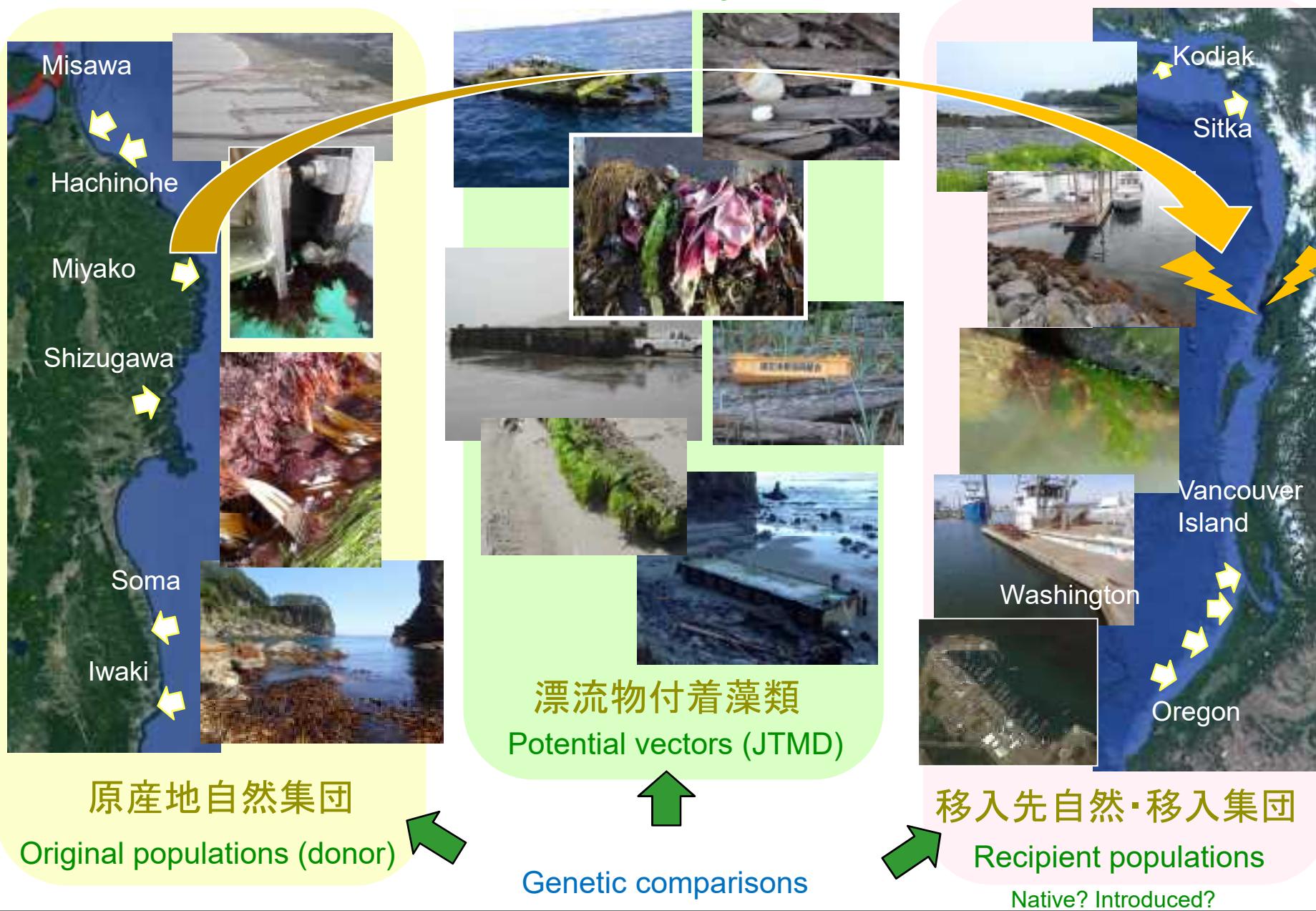
クロバギンナンソウ



ツルツル

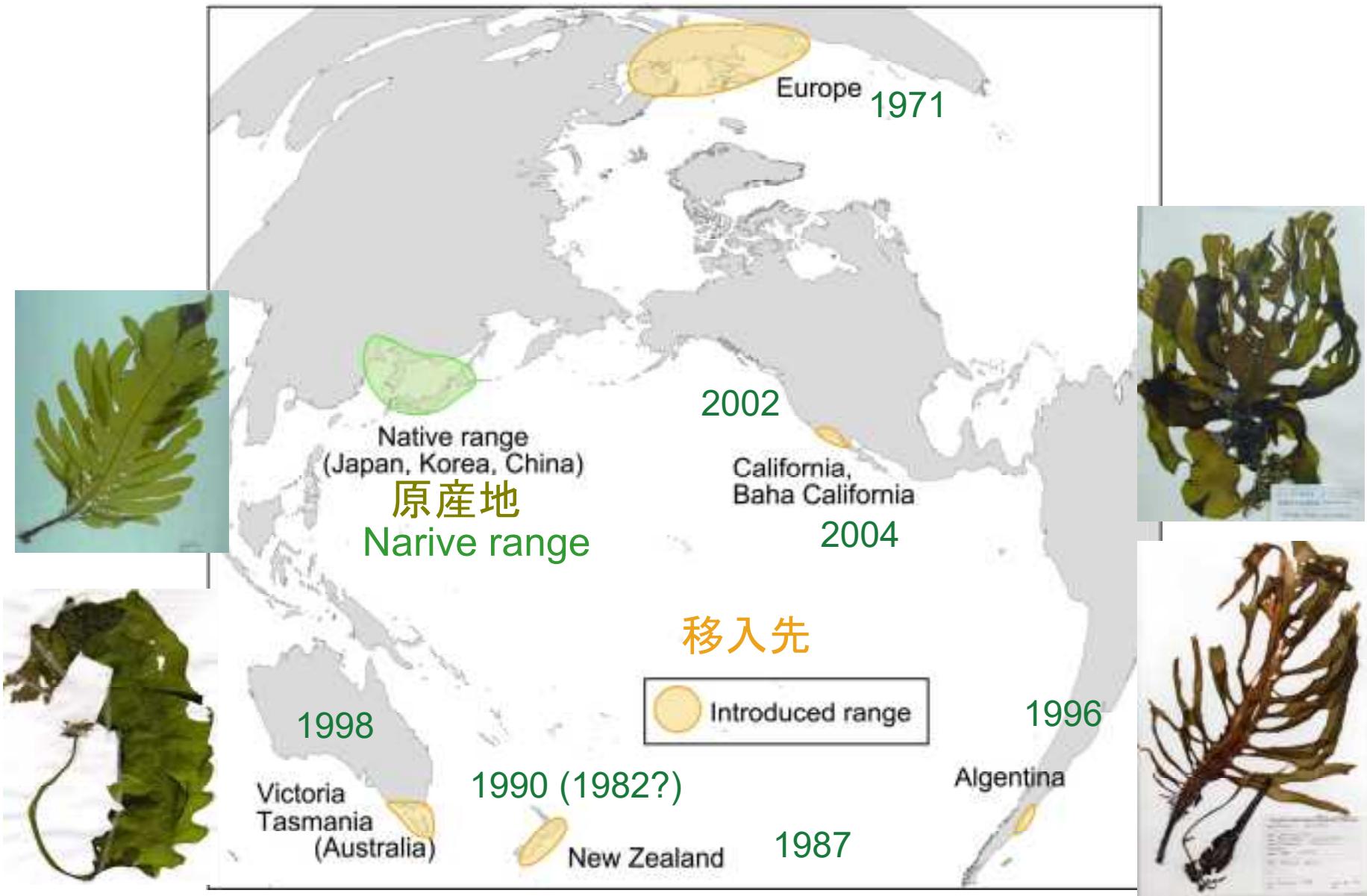
# 東北沿岸, 津波漂流物付着, 北米西岸の海藻類集団の遺伝子比較

Comparisons of specimens from Tohoku region, JTMD and North America



# 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

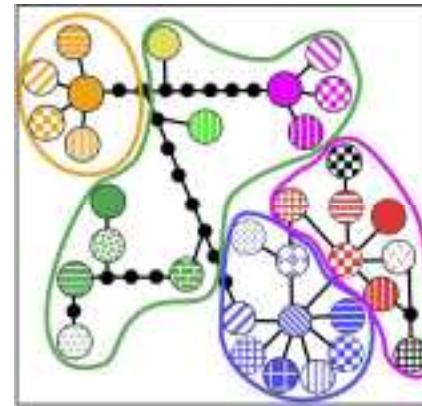
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GAAGCAATTAGCCATGGGATTACCTTTAAATA  
CTATTCTTTACTTCAGGAGCAAGTGTACATGG  
GCTCATCATGCAATTGGCTGGTTAAAAAGAAGC  
TTTACAAGGTTAGGGTAACATTAGGGTTGCAGTTG  
CGTTTACAGGTATGCAAGGTATTGAATATATGCATGCT  
CCTTTGGTATGTCAGATGGGTTATGGTCAGTATT  
TTATATGGCTACGGGATTTCATGGATTCATGTATT  
ATTGAAACAATTCTAGCTATTGTACAATAAGATT  
GTATTGGGACCATTTTA
```

## 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*

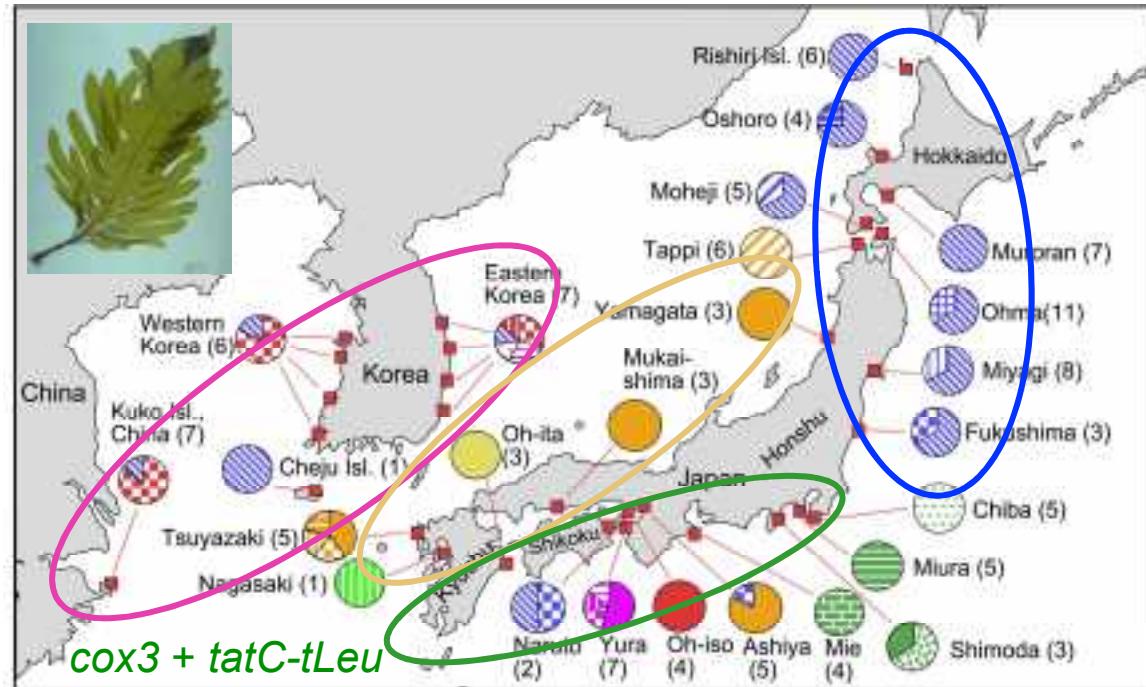


各ハプロタイプ(遺伝子型)間の遺伝的距离

Genetic relationship among haplotypes (spanning tree)

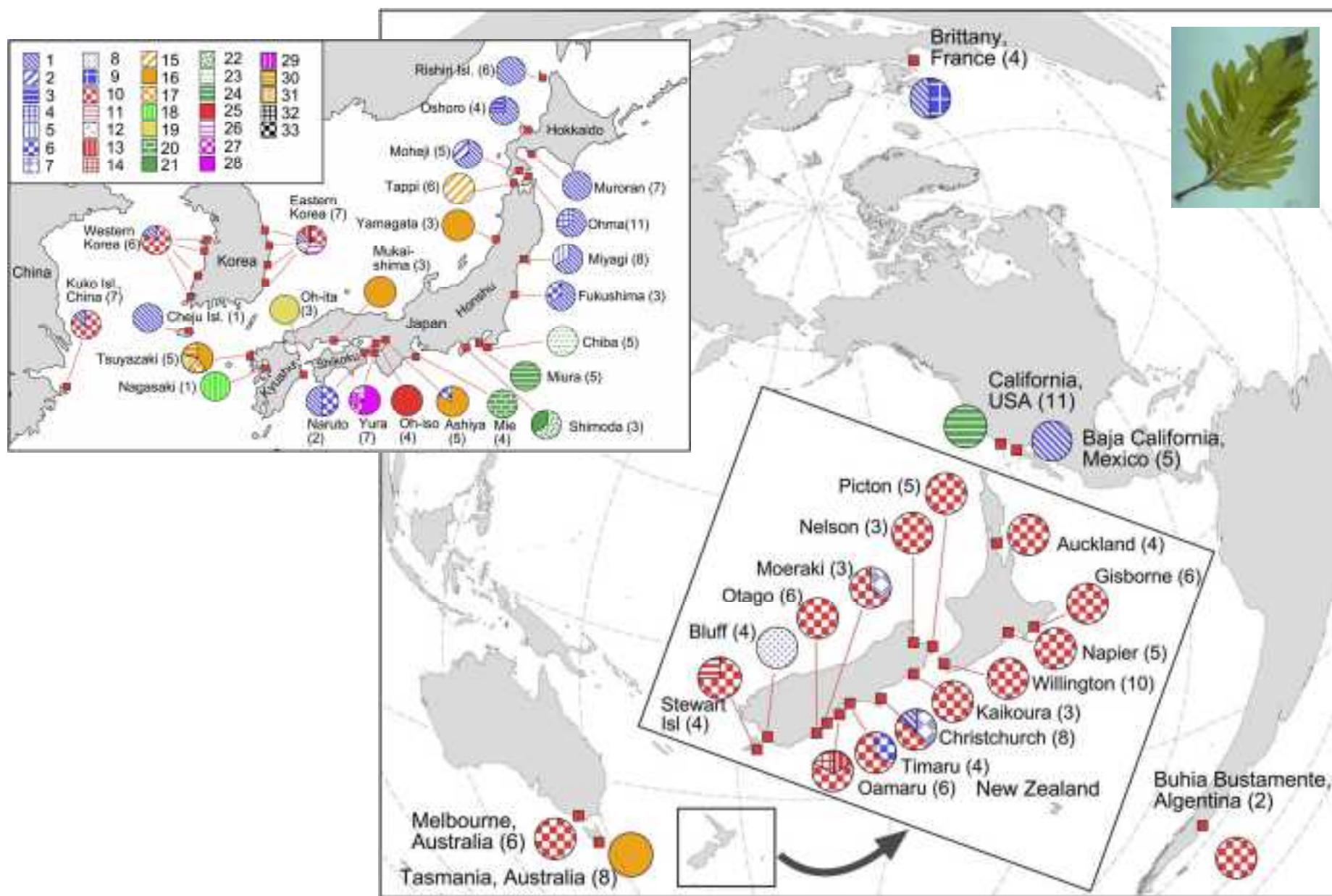
## 各地集団のハプロタイプ分布

### Geographical distribution of haplotypes



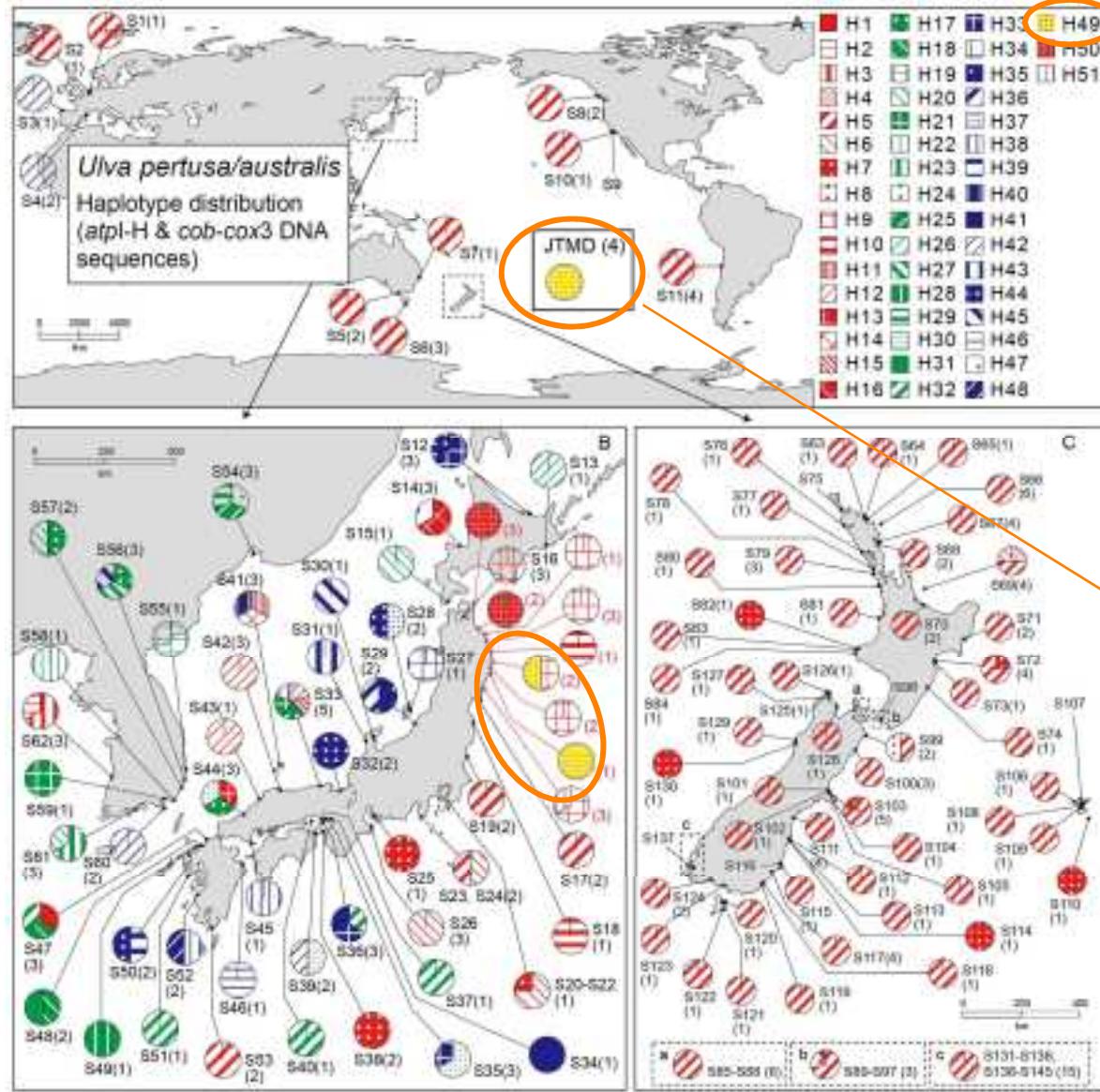
# 世界各地での各ハプロタイプの地理的分布

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

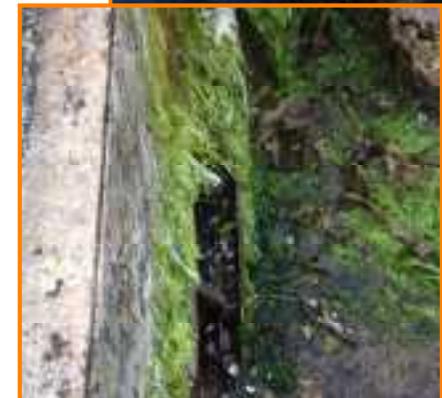


# 緑藻アナオサの各地域集団の遺伝的多様性の解析

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.

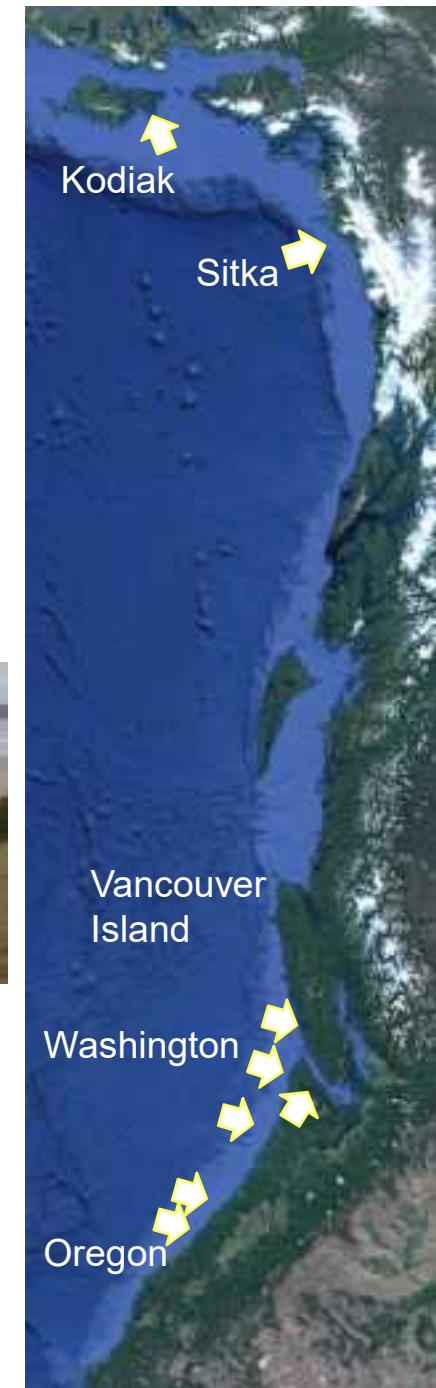


Haplotypes based on mitochondrial  
atpl-H & cob-cox3 gene DNA sequence

# 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

## Identification guide of seaweeds on Japanese tsunami debris



Since 2012 started studies caused by the 2011 Great East Japan Earthquake and Tsunami has been arriving on Northeastern Pacific coasts, which may become introduced to the Northeastern Pacific waters. So far, about 150 species have been identified on debris found via morphological characters, and about 90 of the larger kelps have been present exclusively. Major source of these species is the NE Pacific, where the potential for dispersal is very high, probably mostly by the Kuroshio Current. This identification guide is for this potential to identify them. To fully prevent the introduction and possible invasion of these species, it is important that any new information of these species is delivered 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 debris.

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

**Green algae:** Ulvaceae (Ulva lactuca), Chlorophyceae (Chlorodesmus elongatus, Codium fragile, Ulvularia, Ulva pertusa (=U. australis), Ulva prolifera, Ulva compressa, Ulva rigida), Gracilariales (Gracilaria tikvahiae, Gracilaria intestinalis, Gracilaria confertissima, Gracilaria tikvahiae), Fucales (Laminaria, Laminaria hyperborea, Ascophyllum nodosum, Macrocystis pyrifera, Pyropia yezoensis, Porphyra tenera), Rhodophyta (Ceramium, Polysiphonia, Polysiphonia lachrymans, Polysiphonia elongata, Pyura californica, Ascophyllum nodosum, Pyropia yezoensis, Grateloupia laevigata)

**Red algae:** Rhodophytinae (Cryptothamnion, Chondrus crispus, Chondrus crispus var. giganteus, Cylindrus californicus, Polysiphonia leucosticta, Polysiphonia lachrymans, Pyropia yezoensis, Pyropia yezoensis var. yezoensis, Polysiphonia tenera, Grateloupia laevigata, Pyropia tenera)

### *Uva pertusa (=U. australis)*



**Uva pertusa** (=*U. australis*) forms delicate branching tufts. The species is native to the Indo-Pacific, but tends to have more prominent tufts. Despite distribution range of the species, it has not been reported from the Pacific, but is introduced in the Atlantic Ocean. Usually the species has suggested to be originating from the Atlantic by genetic analysis.

### *Scytoniphon gracilis*



**Scytoniphon gracilis** forms long, branched tufts. The species is native to the Indo-Pacific, but tends to have more prominent tufts. It has high reproductive capacity and forms prostrate growths, having symbiotic dinoflagellates (zooxanthellae). The blade are usually yellow, but may become purple-red. The original distribution range of the species is Northeastern Pacific Ocean, but the species has been introduced to both California and Chile.

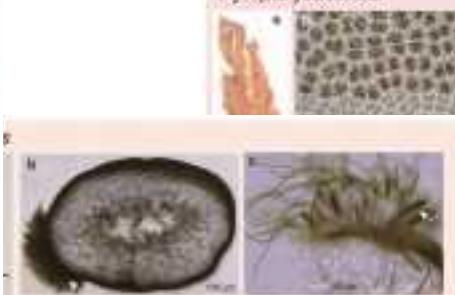
A. Habit of holdfast; B. Habit of blade; C. Close-up of blade



**Scytoniphon gracilis** (Rousseau) is a brown alga found in Japan (only that may exceed several meters in length). The blades have midribs when young, but later becomes smooth. This is a successional or opportunistic species in NE Asia, and widely cultivated in Japan (Kelp pad, China). Presently, the species has reached the Pacific, but whether it is the same or different from the blade in Japan, is not clear under the present status. See further species occurring in the NE Pacific. The species has not been reported from eastern Pacific areas.

## Publication and distribution of identification guide of representative seaweeds on JTMD

### *Pyropia yezoensis*



**Pyropia yezoensis** has branched blade tufts. They have blade and frondous perianths to form separate tufts. Gametangia are located on the uppermost tufts in the subtropics. This species has been introduced to California, but has been reported from coastal Oregon.

A. Habit of holdfast; B. Close-up of the blade; C. Perianth tuft

### *Neopeltidea yendoana*



**Neopeltidea yendoana** is a large annual red alga that tends to occurs in clumps with a wedge-shaped basal portion. The blade are yellowish dark red in color, rounded and nearly oblongate. The main fact has been reported from eastern Pacific coast. Currently the species resembles some form of *Neosparassia* Foslie. Gametangia develops on the blade. Neopeltidea are somewhat robust and not sensitive to cold weather.

A. Habit of holdfast; B. Habit of blade

### *Grateloupia laevigata*



**Grateloupia laevigata** is a red alga occurring attached to the stones and shells. It has a broad base, but large flat branched body, the so-called "rice paper". The blade are mostly red to brownish red. It has been seen at the east coast of North America.

A. Habit of holdfast; B. Close-up of blade

### *Chondrus yender*



**Chondrus yender** has prostrate growth, simple or compactly branched body. The species blade are smooth, but the bladders are present. The species resembles some form of *Chondrus*, but species that occurs in the high continental shelf of WA, but is also seen in the sea. In Africa, it occurs in several countries, including Mozambique (Mozambique). The species has not yet been reported from Northeastern Pacific.

A. Habit of holdfast; B. Close-up of blade

### *Polyneura ciliata*



**Polyneura ciliata** forms a short stalk and an irregularly branched foliation that can be easily split. The blades are soft and slippery when young, but later becomes rigid and leaf-like. The lower part has a layer of thick wavy reddish-brown rhizome. Chromatophores (green cells) are observed on the upper blade. The species has a heterophylly, the bottom appearing brownish-greenish greenish-yellow and a slender sporephyte (or sterile shoot), representing the life history observed in the subtropics giving the blade and rhizome appearance. The species has a relatively broad circumglobal range. However, in the Northeastern Pacific, it has only been found in California.

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Thank you for your attention.