Barnacle fouling on the hull of an ocean-going bulk carrier visited the Port of Kawasaki and the risk assessment of their invasion

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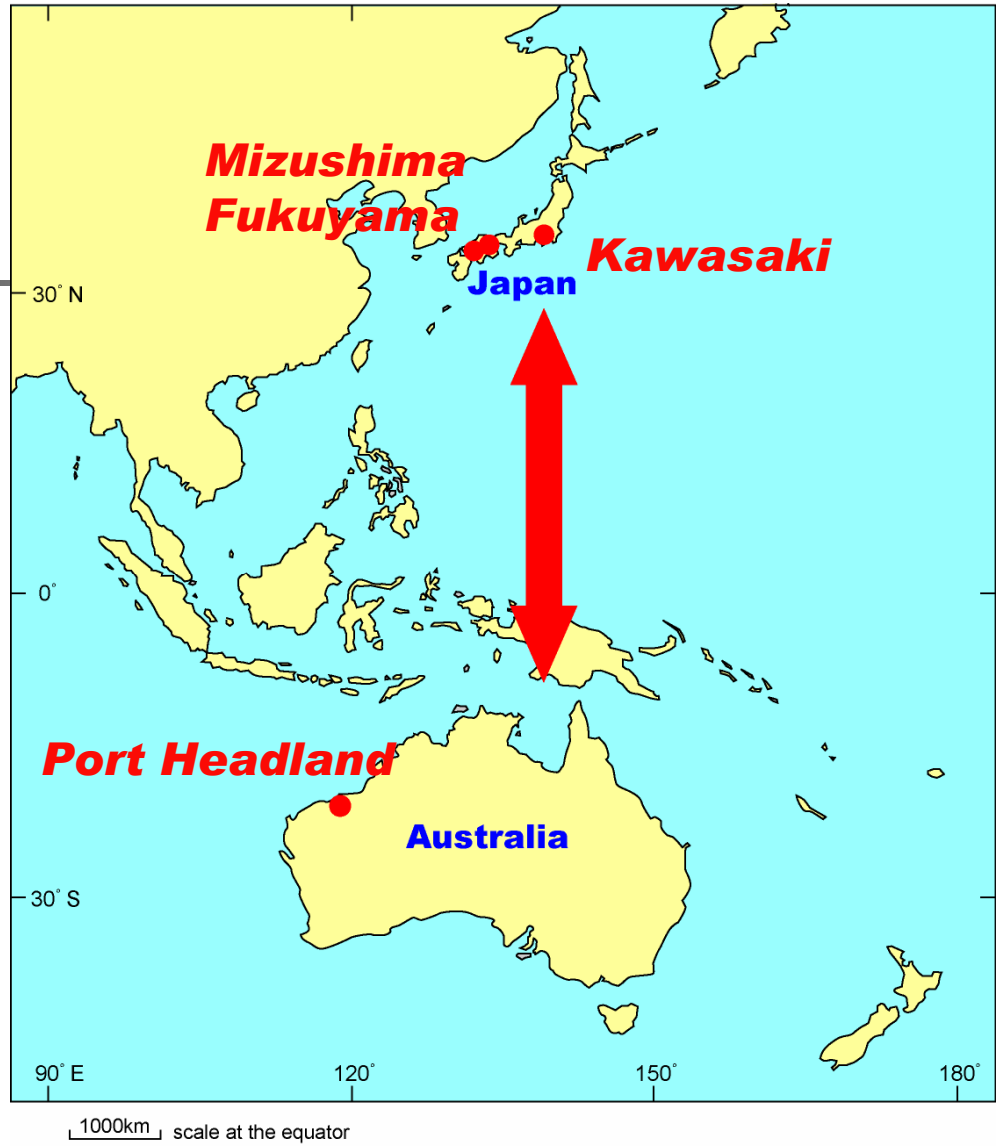
Points

- Difference of barnacle condition by hull location
  - Species composition
  - Survival rate
  - Incubation rate
- Risk assessment
  - The difference of invasion risks by species
  - The estimation of the donor port for the candidate of invasive species to the Port of Kawasaki

Surveyed ship

- Ore Carrier: 203,180DWT
- Ports of call: Japan (Kawasaki, Mizushima, and Fukuyama)
  Australia (Mainly Port Headland)
- Date and site: 22nd Sept., 2007 at Mizushima Port

Her route &
ports of call



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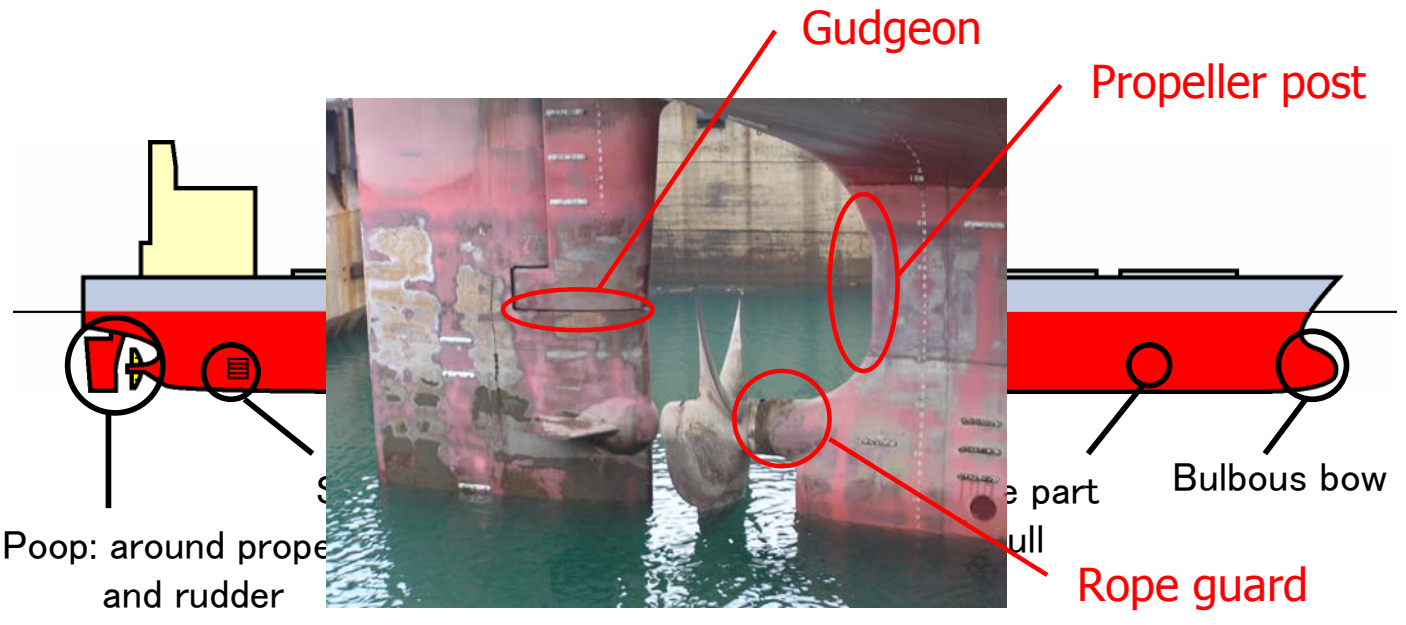
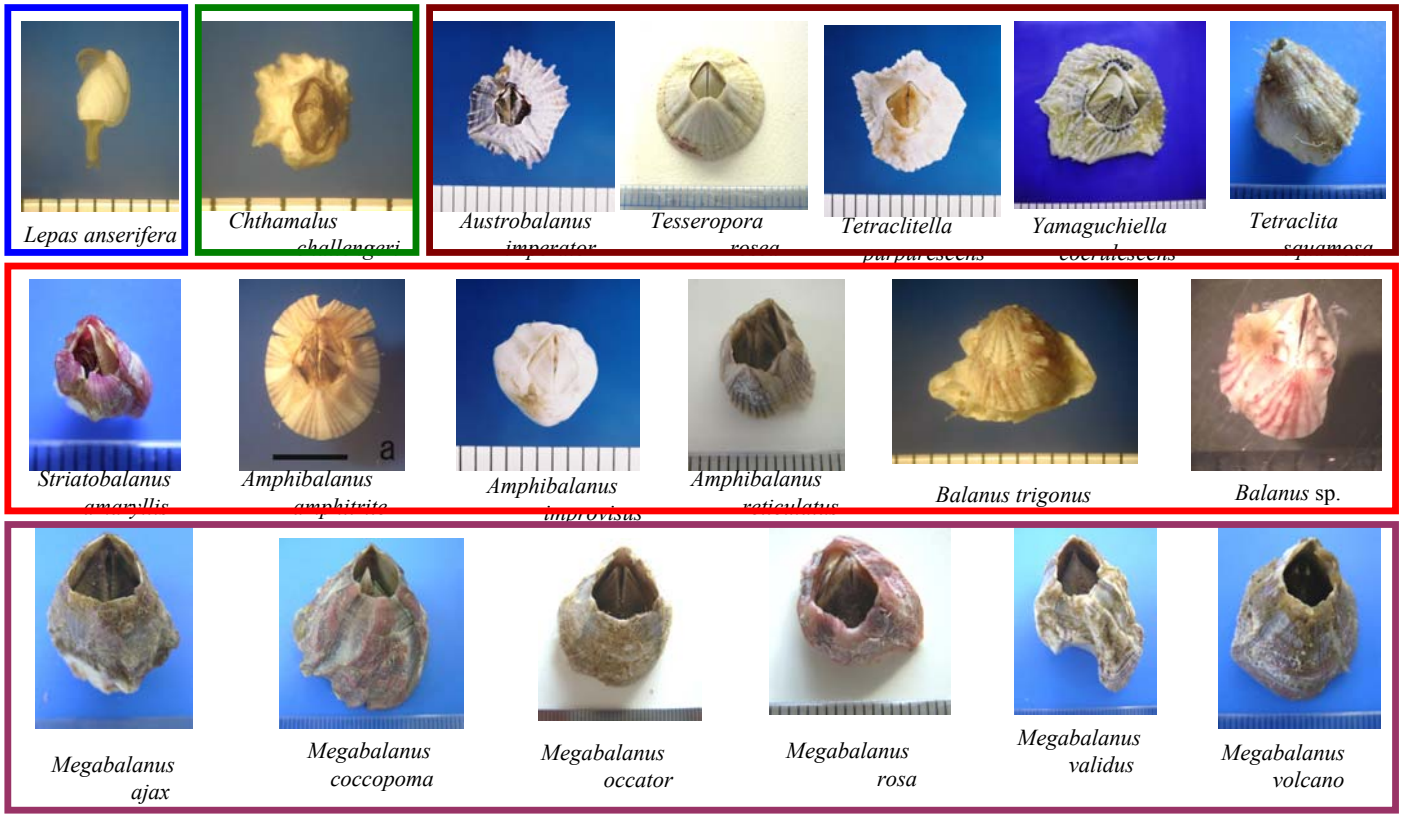
Hull locations surveyed

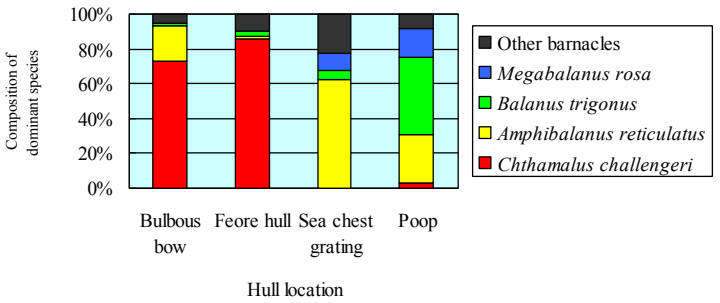


(Photographed by T. Hanyuda)

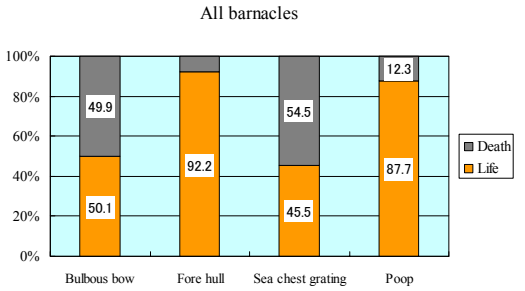
Lepadidae: 1species Chthamalidae：1 species
Tetraclitidae： 5 species Balanidae:（Balaninae: 8 species
Megabalaninae: 6 species）



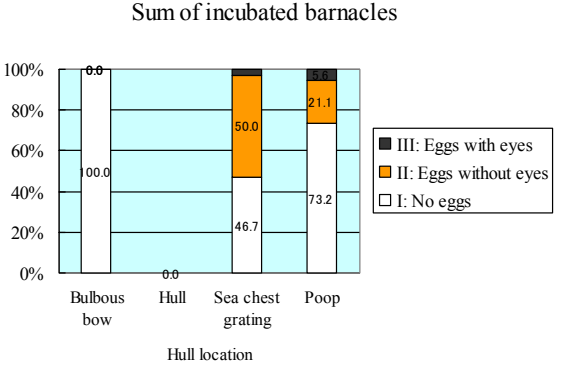
Difference of barnacle condition by hull location



Species composition



Survival rate



Incubation rate

Invasion risk assessment

- Recipient port: The Port of Kawasaki
- Candidate species: Twelve species which never discovered at the Port of Kawasaki and its adjacent waters were chosen
- Other conditions

1. As a donor, only some Australian ports trade with the Port of Kawasaki were chosen
2. Postulated that candidate species were carried by not only bulk carriers but also other ocean-going ships from Australia
3. Included also *Austrominius modestus* as a candidate which was estimated as the most probable species to be introduced in our previous survey

Equation for the calculation of *IP*

$$IP = \frac{1}{c} \cdot \left(\sum_{j=1}^{m} \left(\frac{v_j \cdot ES_j}{t_j} \right) + \sum_{j=1}^{m} \left(\frac{b_j \cdot ES_j}{t_j} \right) \right)$$

(a part of Hayes et al. 2005)

Visit score

Ballast score

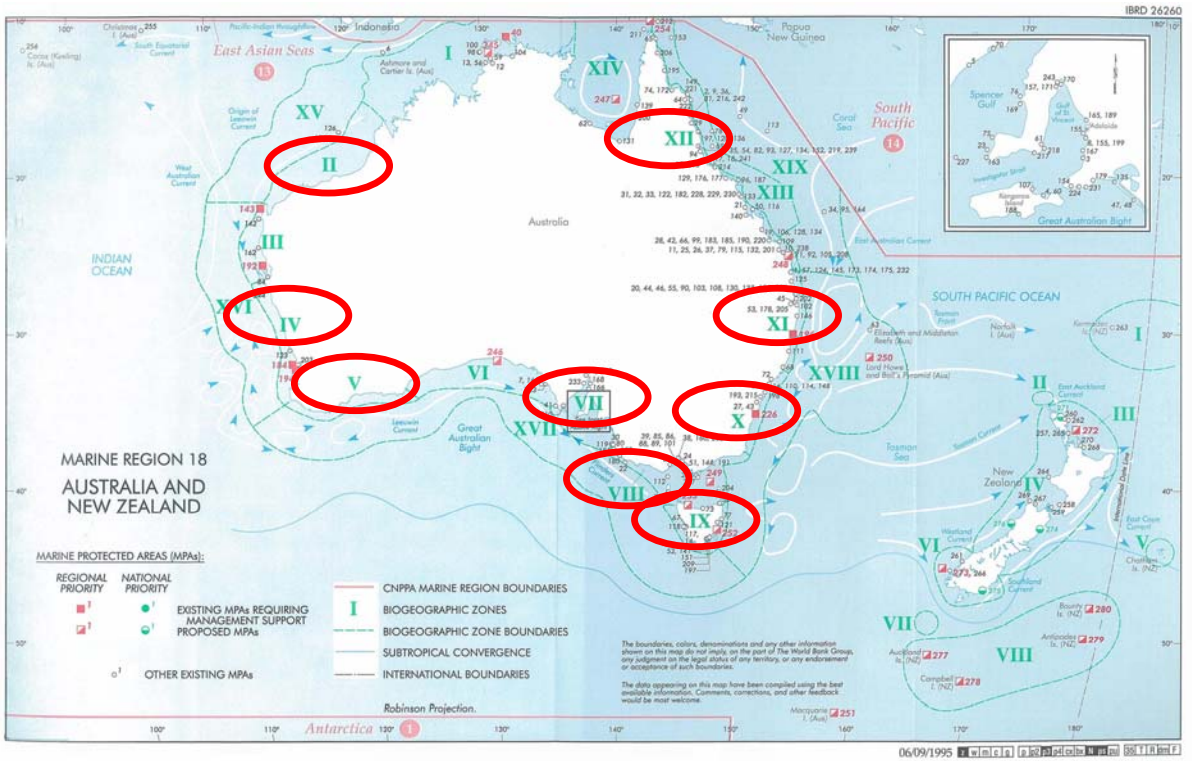
IP: Invasion Potential for each species
v : Ship visit to the recipient port
ES: Environmental similarity
b : Discharged ballast water at the recipient port
t : Journey duration
j : Bioregion/or port infected by invasive species
c : Constant given by the sum of hull fouling and ballast water invasion score across all bioregions

$$ES = 1 - \left(\frac{d}{90} \right)^{\beta}$$

d : Absolute difference of the latitude between donor and recipient port
β : Parameter to adjust the "strength" of the difference between the latitude of the donor and recipient port

What is the bioregion?

Used IUCN bioregion



(Kelleher et al. 1995)

Results of two scores by bioregion

$$IP = \frac{1}{c} \cdot \left(\sum_{j=1}^{m} \left(\frac{v_j \cdot ES_j}{t_j} \right) + \sum_{j=1}^{m} \left(\frac{b_j \cdot ES_j}{t_j} \right) \right)$$

Visit score

Ballast score

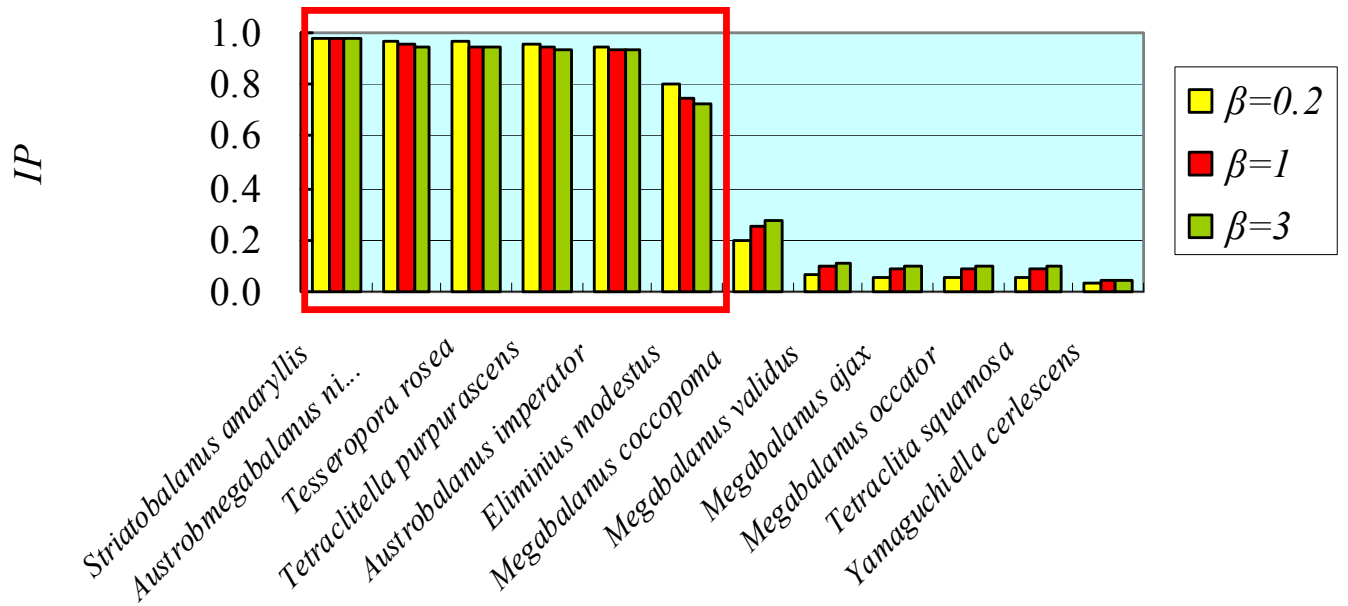
Results

IUCN Bioregion	Mean distans (mile)	Mean jouney duration (day)	Difference of Lat.	Ship visit	Volume of discharged BW in Kawasaki	ES *(β=0.2)*	ES *(β=1)*	ES *(β=3)*	Visit score *(β=0.2)*	Visit score *(β=1)*	Visit score *(β=3)*	Ballast Water score *(β=0.2)*	Ballast Water score *(β=1)*	Ballast Water score *(β=3)*
ASR-X	4,329	11.2	1.7	13	770	0.5478929	0.9811111	0.9999933	0.6359472	1.1387897	1.1607065	37.667640	67.451389	68.749537
ASR-XI	3,934	10.0	8.1	2	166	0.3821991	0.910000	0.999271	0.0764398	0.1820000	0.1998542	6.3445059	15.106000	16.587899
ASR-XII	3,904	8.7	13.3	42	0	0.3177841	0.8522222	0.9967728	1.5282748	4.0984733	4.793640	0	0	0
ASR-V	4,902	13.7	1.1	7	0	0.585590	0.9877778	0.9999982	0.3003027	0.5065527	0.5128196	0	0	0
ASR-VII	5,448	14.1	2.5	1	0	0.5116407	0.9722222	0.9999786	0.0362866	0.0689519	0.0709205	0	0	0
ASR-VIII	4,878	13.4	2.6	2	4	0.5077948	0.9711111	0.9999759	0.0757903	0.144942	0.1492501	0.1515805	0.2898839	0.2985003
ASR-IX	4,833	15.3	5.8	3	0	0.4221208	0.9355556	0.9997324	0.0827688	0.183442	0.196026	0	0	0
ASR-IV	4,430	12.0	4.5	10	0	0.450720	0.950000	0.999875	0.3755998	0.7916667	0.8332292	0	0	0
ASR-II	3,650	10.3	15.0	48	0	0.3011729	0.8333333	0.995370	1.4035241	3.8834951	4.6386192	0	0	0

c value

	Visit score *(β=0.2)*	Visit score *(β=1)*	Visit score *(β=3)*	Ballast Water score *(β=0.2)*	Ballast Water score *(β=1)*	Ballast Water score *(β=3)*
All bioregion	4.5149339	10.998314	12.555065	44.163727	82.847273	85.635936

Results of the calculation of *IP* at the Port of Kawasaki



Add another condition

Previous *IP* is resulted only from the difference of the latitude

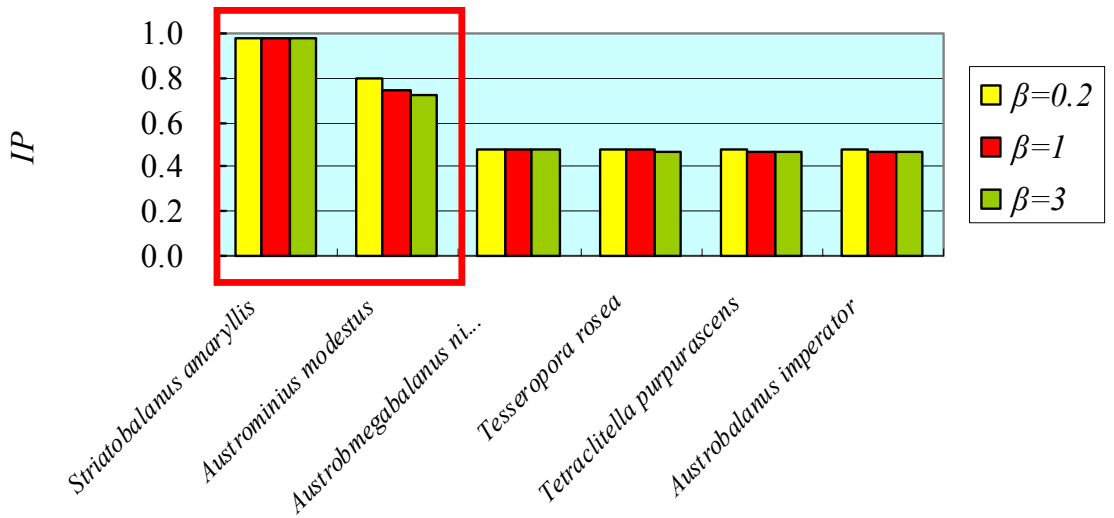
Added another environmental condition of sheltered or exposed

Sheltered····1
Exposed ····2

$$ES(H) = 1 - \left(\frac{d}{2} \right)$$

Species	*ES(H)*
Striatobalanus amaryllis	1
Austrobmegabalanus nigresce	0.5
Tesseropora rosea	0.5
Tetraclitella purpurascens	0.5
Austrobalanus imperator	0.5
Austrominius modestus	1

Final *IP*


IP
1.0
0.8
0.6
0.4
0.2
0.0
β=0.2
β=1
β=3
Striatobalanus amaryllis
Austrominius modestus
Austrobmegabalanus ni...
Tesseropora rosea
Tetraclitella purpurascens
Austrobalanus imperator

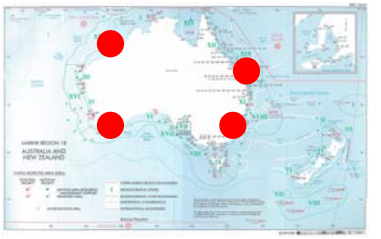
Next issue is the origin of these two species

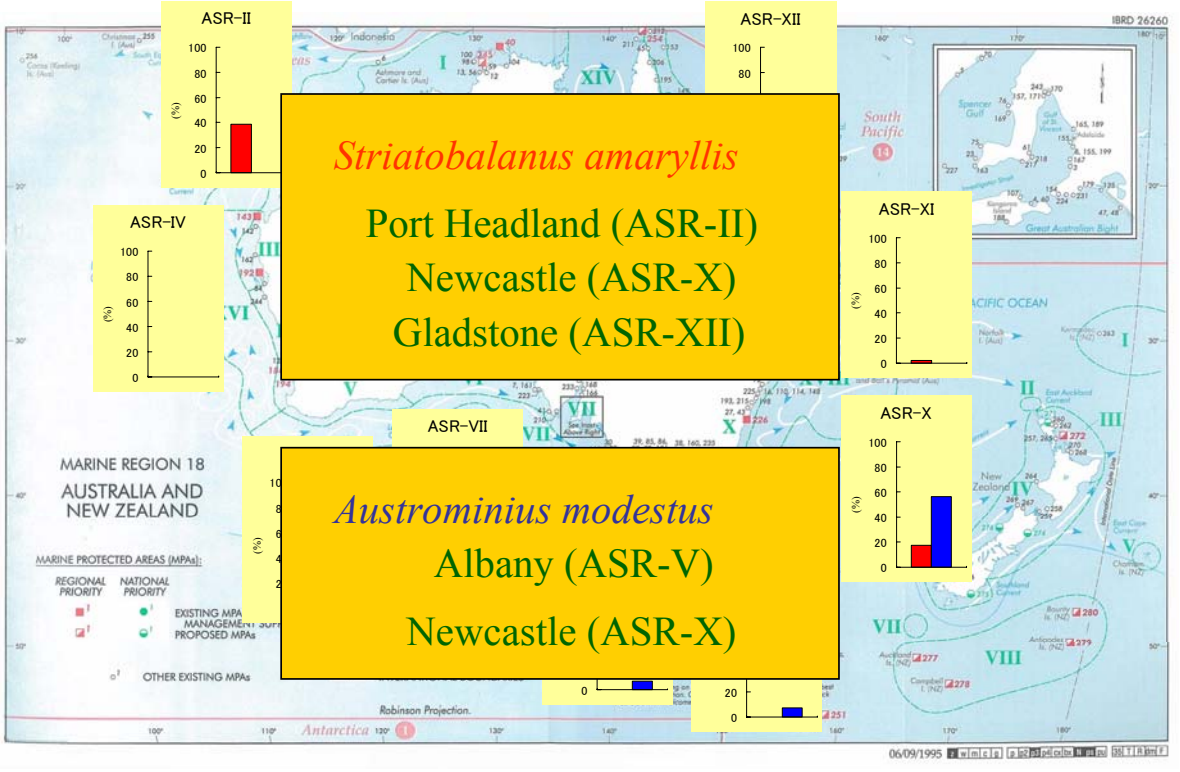
When we discussed the issue, we presumed that origins of these two species might have been different by vector like a hull fouling and a ballast water

We used visit and ballast score to presume their origin, because they related to hull fouling and ballast water respectively

Origin of candidate species to the Port of Kawasaki（1）

（Relative importance of bioregion：Hull fouling）



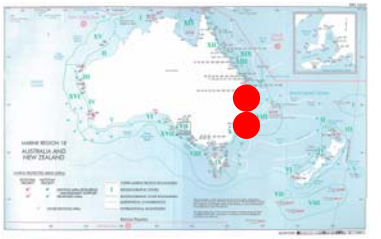


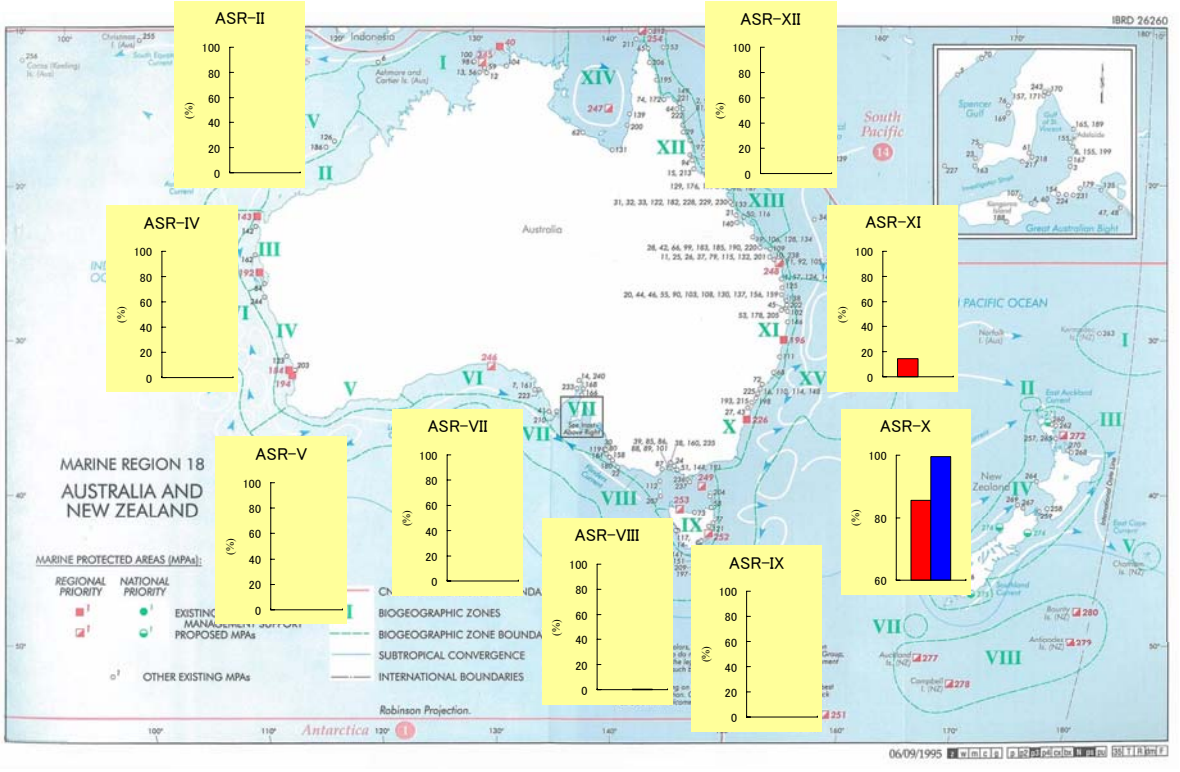
Striatobalanus amaryllis:

Austrominius modestus:

Origin of candidate species to the Port of Kawasaki（2）

（Relative importance of bioregion：Ballast water）





Striatobalanus amaryllis:

Austrominius modestus:

We have to be careful of next things

- Ships from those two bioregions with ballast water are PCCs (Pure Car Carrier)
- Since PCCs go to various countries, the origin of ballast water may not always be from Australia
- The age of ballast water may be old enough to kill barnacle larvae in it, because PCCs hardly discharge their ballast water

The ballast water from those bioregions in Australia does not contribute to the introduction of barnacles

Conclusions

From hull fouling survey

- Ships' hulls obviously contribute to the dispersal of barnacles across the sea, with various species attached to each hull location

From invasion risk assessment

- High-risk species likely to be introduced to the Port of Kawasaki by hull fouling were *Striatobalanus amaryllis* and *Austrominius modestus*

- Candidate ports of former species are Port Headland, Gladstone, and Newcastle and those of latter are Albany and Newcastle

- Ballast water may not contribute to the introduction of these two species

Our future plans

- We should be careful about ships' hulls come from candidate ports to prevent new introduction to the Port of Kawasaki
- We would like to apply our method to other species and other Japanese ports as many as possible to solve the introduction issue in Japan

Acknowledgement

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