

COMMUNICATION

Imposex in Sea Snails, Caused by Organotin (Tributyltin and Triphenyltin) Pollution in Japan: a Survey

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A country-wide survey and laboratory experiments on imposex (a superimposition of male sex organs on female sea snails) in Japanese sea snails were carried out: 38 species were observed to be affected by imposex. For the rock shell, *Thais clavigera*, the percentage occurrence of imposex was 100% at almost all sites surveyed. The degree of imposex seemed to be positively correlated with the concentrations of tributyltin (TBT) and triphenyltin (TPT) in the species. The results of laboratory experiments showed that imposex in *T. clavigera* was initiated and promoted by both TBT and TPT. Many oviduct-blocked individuals, which were thought to be sterile, were observed in *T. clavigera* at sites near marinas and harbours. The effects of organotin pollution on the population of *T. clavigera* were observed at the sites near marinas. From the results of the additional country-wide survey on imposex in *T. clavigera* during 1993–1995, serious organotin pollution and imposex symptoms in the species are still continuing in Japan. © 1997 by John Wiley & Sons, Ltd.

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Hermaphroditism is not usually observed in most sea snails. However, pseudohermaphroditism has been observed and reported in the dog-whelk, *Nucella lapillus* (Muricidae: Neogastropoda),¹

and also in the mud snail, *Nassarius obsoletus* (= *Ilyanassa obsoleta*) (Nassariidae: Neogastropoda).^{2,3} Such pseudohermaphroditism is called imposex,² defined as a superimposition of male sex organs (penis and vas deferens) on female sea snails.² In some species, imposex may bring about reproductive failure and consequential population decline.^{4–7} This is suggested to be the case for the Japanese whelk (ivory shell), *Babylonia japonica* (Buccinidae: Neogastropoda).⁸ It is accepted that imposex is induced by tributyltin (TBT) compounds, which have been used worldwide in antifouling paints for ships and fishing nets.^{9,10} As of December 1994,

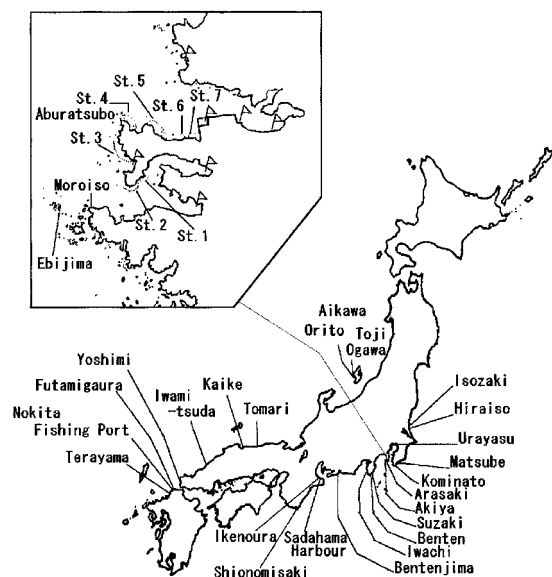


Figure 1 Sampling sites for specimens of *Thais clavigera* and *T. bronni* (during 1990–1992). The flag symbols indicate marinas, harbours and piers around Aburatsubo on the Miura Peninsula.¹¹

imposex had been observed and reported in more than 70 species of sea snails around the world. In Japan, although the occurrence was known, a detailed survey had not been conducted. Here, we report the results of a country-wide survey and laboratory experiments on imposex in Japanese sea snails.

Thirty-eight species (32 neogastropods and six mesogastropods) were found to be affected by imposex in 68 species of Japanese sea snails surveyed (as of June 1995) (Table 1). This study represents the first report on imposex in mesogastropods. Further surveys are expected to

Table 1 Species of Japanese sea snails which have been observed to be affected by imposex (up to June 1995)

Mesogastropoda	
Strombidae	<i>Strombus luhuanus</i>
Naticidae	<i>Neverita didyma</i>
Cymatiidae	<i>Fusitriton oregonensis</i>
	<i>Monoplex echo</i>
	<i>Charonia sauliae sauliae</i>
Tonnidae	<i>Tonna luteostoma</i>
Neogastropoda	
Muricidae	<i>Rapana venosa venosa</i>
	<i>Ergalatax contractus</i>
	<i>Ceratosoma burnetti</i>
	<i>Cronia pothuauii</i>
	<i>Morula musiva</i>
	<i>M. granulata</i>
	<i>M. marginatra</i>
	<i>Drupella fragum</i>
	<i>Thais clavigera</i>
	<i>T. bronni</i>
	<i>T. luteostoma</i>
	<i>Nucella freycineti heyseana</i>
	<i>N. freycineti alabaster</i>
	<i>N. emarginata</i>
	<i>N. lima</i>
Buccinidae	<i>Japeuthria ferra</i>
	<i>Searlesia fuscolabiata</i>
	<i>Pusiosoma mendicaria</i>
	<i>Kelletia lischkei</i>
	<i>Babylonia japonica</i>
	<i>Volutharpa ampullacea perryi</i>
	<i>Buccinum middendorffi</i>
	<i>B. opisthoplectum</i>
	<i>Neptunea arthritica arthritica</i>
Melongenidae	<i>Hemifusus tuba</i>
Nassariidae	<i>Reticunassa festiva</i>
Fascioliidae	<i>Fusinus perplexus perplexus</i>
Cancellariidae	<i>Sydaphera spengleriana</i>
Conidae	<i>Virroconus ebraeus</i>
	<i>V. fulgetrum</i>
	<i>Virgiconus lividus</i>
	<i>Conus marmoreus bandanus</i>

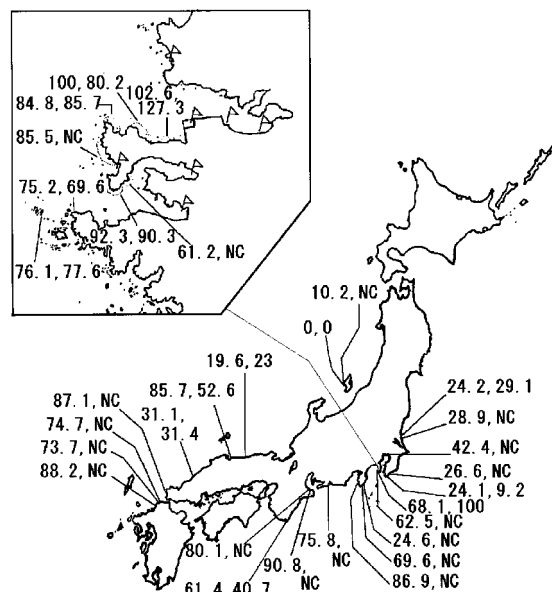


Figure 2 Observed values of the RPL index in *T. clavigera* and *T. bronni* (during 1990–1992). The numerals on the left are for *T. clavigera* and the right-hand ones for *T. bronni*. NC means no value of the RPL index was obtained at the site, because no sample was collected.

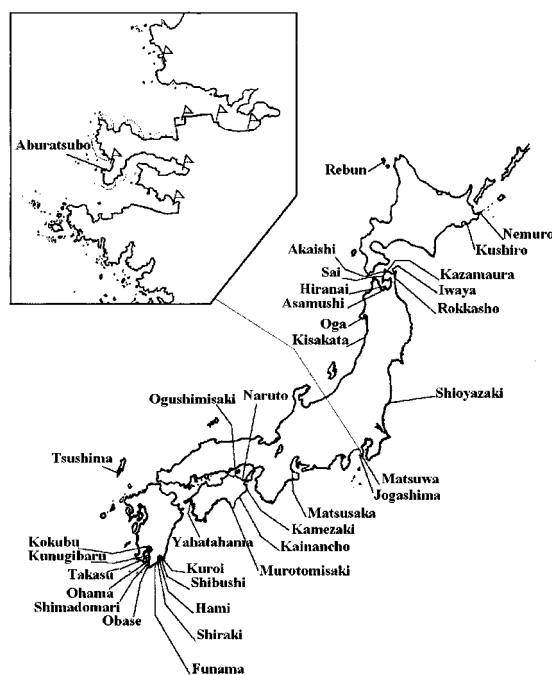


Figure 3 Sampling sites for specimens of *T. clavigera* and other kinds of muricid gastropods (during 1993–1995). The flag symbols indicate marinas, harbours and piers around Aburatsubo on the Miura Peninsula.

reveal additional species of sea snails that are affected by imposex.

Occurrence rates of imposex in rock shells, *Thais clavigera* and *T. bronni* (Muricidae: Neogastropoda) were 100% at almost all sites surveyed during 1990–1992 (32 sites in Japan; Fig. 1). The relative penis length (RPL) index (%) is defined as a ratio of mean penis length in females to that in males, and is considered to show the degree of imposex in these species. The observed values of this index were higher at sites in Miura Peninsula (Aburatsubo, Moroiso, Ebijima, Arasaki and Akiya), Lake Hamana (Bentenjima), Mie Prefecture (Ikenoura and Sadahama harbour) and the northern part of Kyushu (Futamigaura, Nokita fishing port and Terayama), which were near harbours and marinas (Fig. 2), and were positively correlated with the concentrations of TBT and triphenyltin (TPT) compounds in both species.¹¹ TPT as well as TBT had been widely used in antifouling paints in Japan. At sites near marinas and harbours many individuals were found to have deformities, including oviduct blockage by vas

deferens formation.¹¹

The results of injection experiments on six kinds of organotin compounds (TBT, TPT and their metabolites) using *T. clavigera* showed that TPT as well as TBT had strong effects on the initiation and promotion of imposex in this species. The results are quite similar for both compounds; the effects of imposex promotion are estimated to be approximately the same, from the relationships between tissue concentration and mean penis length in females, for TBT and TPT.¹²

Judging from the flow-through exposure experiments over three months, imposex is induced in adult females of *T. clavigera* at an environmental concentration of approximately 1 ng l^{-1} of TBT. The threshold body burden of TBT inducing imposex is also estimated to be about 20 ng g^{-1} wet weight (0.06 nmol g^{-1} wet weight) in this species.¹³

As many individuals were found to have deformities, including oviduct blockage by vas deferens formation, in *T. clavigera* at sites near

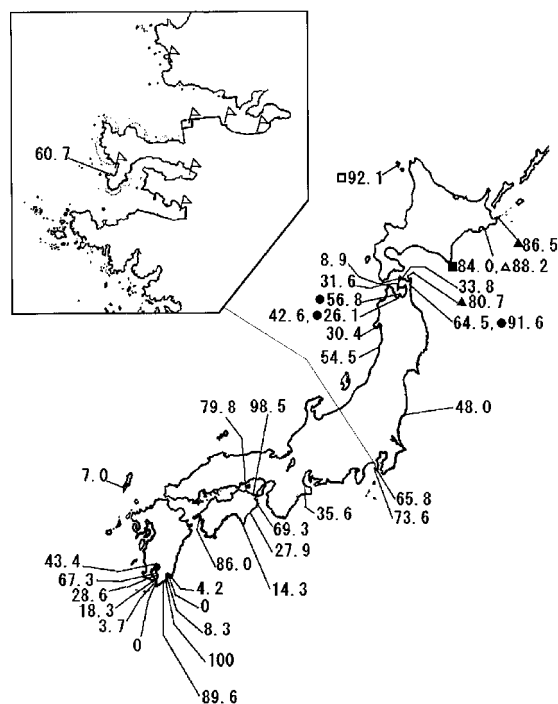


Figure 4 Observed values of the RPL index in *T. clavigera* and other kinds of muricid gastropods (during 1993–1995). Unmarked values, *T. clavigera*; ●, *T. bronni*; ▲, *Nucella freycineti heyseana*; △, *N. emarginata*; ■, *N. freycineti alabaster*; □, *N. lima*.

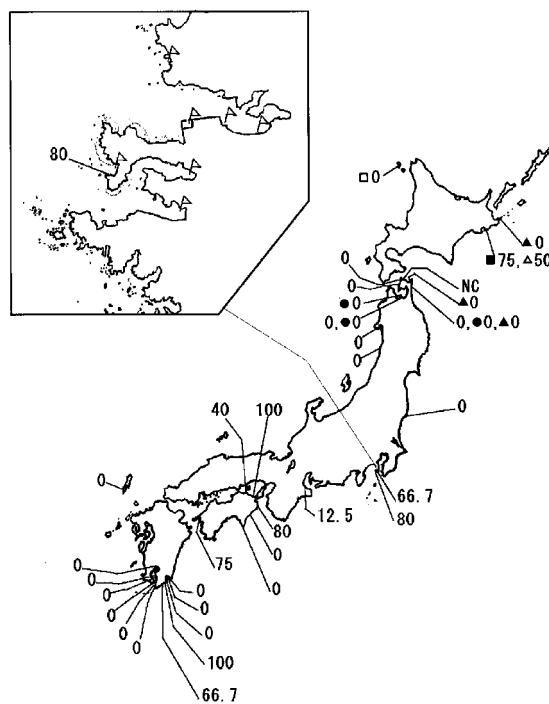


Figure 5 Percentage occurrence of oviduct-blocked individuals, which are thought to be sterile, in *T. clavigera* and other kinds of muricid gastropods (during 1993–1995). Unmarked values, *T. clavigera*; ●, *T. bronni*; ▲, *N. freycineti heyseana*; △, *N. emarginata*; ■, *N. freycineti alabaster*; □, *N. lima*.

Table 2 Organotin concentrations in tissue of the rock shell, *Thais clavigera*, during 1990–1991

Site	TBT (ng g ⁻¹ wet wt)		TPT (ng g ⁻¹ wet wt)		RPL index
	Male	Female	Male	Female	
Isozaki	17.0	18.0	28.1	36.9	24.2
Kominato	14.0	27.7	46.0	57.1	24.1
Urayasu	24.5	62.8	95.8	149.4	42.4
Aburatsubo					
Station 1	388.0–500.5	—	1176.6–2714.1	—	61.2
Station 2	231.3	267.3	711.1	738.6	92.3
Ebijima	40.3	55.1–98.3	309.9	242.4–351.5	76.1
Arasaki	102.6	91.5–153.8	113.4	85.8–172.4	68.1
Bentenjima	73.4	333.5–400.0	230.6	666.0–782.1	75.8
Sadahama Harbour	103.0	116.4–197.5	136.5	213.9–588.0	90.8
Shionomisaki	39.7	48.4–65.5	37.1	43.9–89.4	61.4
Iwamitsuda	55.9	34.3	38.0	86.7	31.1
Tomari	33.4	52.0–63.4	41.1	40.5–81.5	19.6
Aikawa (Orito)	13.7	10.6	16.5	4.7	0

marinas and harbours, the effects of organotin pollution on the population of *T. clavigera* were observed at Aburatsubo on the Miura Peninsula (Kanagawa Prefecture) from October 1990 to April 1992. The concentrations of TPT, both in seawater and in organisms, decreased gradually during this period, but the concentrations of TBT remained high. Deformed individuals with blocked oviducts, and other reproductive deformities, were observed at all stations; occurrence rates were in the range of 40–80%. Higher rates were recorded at stations in the inner part of Aburatsubo Bay, close to a marina. Near the marina, neither spawning behaviour nor spawned egg capsules were observed, population densities were lower and no juveniles were collected during the survey. These phenomena were considered to be caused mainly by reproductive failure due to imposex, and were possibly enhanced by the TBT pollution in the bay. TBT pollution may also cause the death of larvae flowing into the bay, and thus result in recruitment failure.¹³

An additional country-wide survey on imposex in *T. clavigera* was carried out during 1993–1995 (Fig. 3). Percentages occurrence of imposex in this species was still 100% at almost all the sites surveyed. The observed values of the RPL index were also still high at sites near marinas (Aburatsubo), harbours (Kushiro, Naruto and Ogushimisaki), some fishing ports (Rebun, Nemuro, Iwaya, Rokkasho, Matsuwa, Kamezaki, Yahatahama, Kunugibaru, Shiraki and Funama) and dockyards (Jogashima) (Fig.

4). Percentage occurrence of oviduct-blocked individuals, which were thought to be sterile, was also high at those sites (Fig. 5). These results are considered to be caused by persistence of organotin compounds such as TBT and TPT in the marine environment, suggesting their ongoing use in antifouling paints, as well as by survival of the individuals which have already been seriously affected by imposex, because tissue concentrations of TBT and TPT in *T. clavigera* were high and they were predominant compared with their metabolites at some sites mentioned above (e.g. Jogashima and Shiraki). Thus, in Japan, organotin pollution still remains and imposex symptoms in sea snails have been serious.

The authors will report further results of field studies and laboratory experiments on imposex in Japanese sea snails mentioned above, in a later publication. Details of some observed organotin levels are given in Table 2, determined by GC-FPD after the propylation of organotin compounds in the rock shell.¹¹

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