

TABLE 1

**A Summary of Phycotoxins and Tetrodotoxins (TTX) Associated with Gastropod Molluscs. Maximum Recorded Values are Given. Species Names are as Given in Original Publications**

| Gastropod species <sup>a</sup>   | Toxin Source <sup>b</sup>  | Toxin Level <sup>c</sup>   | Notes  | Location  | Ref.  |
|--|--|--|--|---|---|
| <i>Littorina sitkana</i>   | <i>Gonyaulax tamarensis</i>  | Trace  | Whole snails   | Washington  | MacDonald (1970)  |
| <i>Littorina littorea</i><br><i>Polinices heros</i>  | Probably <i>A. tamarensis</i>  | 72<br>1450   | 2 cases of PSP; victims<br>ate both species of snail                                   | Massachusetts   | Tufts et al. (1975);<br>Tufts (1979)  |
| <i>Littorina littorea</i>  | <i>Alexandrium tamarensis</i>  | 37   | Whole snails   | New Brunswick, Canada                                       | Matter (1993)   |
| <i>Thais lapillus</i><br><i>Buccinum undatum</i>   | <i>G. tamarensis</i><br><i>G. tamarensis</i><br><i>G. excavata</i><br><i>G. tamarensis</i> | 34<br>Whole body: 608<br>digestive gland: 1600<br>Not given<br>1096 MU 100 g <sup>-1</sup>       | 12 cases of PSP<br>4 deaths<br>Snail mortalities<br>Fed toxic mussels in<br>laboratory | Maine<br>Quebec<br>Quebec<br>Faroe Islands<br>Great Britain | Goggins (1961)<br>Medcof (1972);<br>Prakash et al. (1971)<br>Mortensen (1985)<br>Ingham et al. (1968) |
| <i>Turbo marmorata</i><br><i>Turbo argyrostoma</i><br><i>Tectus pyramis</i><br><i>Tectus nilotica maxima</i> | <i>Jania</i> sp.   | 4.2 MU g <sup>-1</sup><br>20 MU g <sup>-1</sup><br>19 MU g <sup>-1</sup><br>5 MU g <sup>-1</sup> | All grazers  | Japan   | Yasumoto and Kotaki<br>(1977, 1983); Kotaki<br>et al. (1981, 1983);<br>Kanno et al. (1976)            |
| <i>Zidona angulata</i>   | <i>A. excavatum</i>  | Not given  | One mild case of PSP   | Argentina   | Elbusto et al. (1991)   |
| <i>Haliotis tuberculata</i><br><i>Littorina</i> sp.<br><i>Patella</i> sp.                                    | <i>Gymnodinium</i><br><i>catenatum</i> (?)   | 0.78 ng/g meat<br>None detected<br>None detected   | All browsers; tests for<br>DSP negative<br>in all species                              | Spain   | Martinez et al. (1993)  |
| <i>Oliva vidua fulminans</i>   | <i>Pyrodinium</i><br><i>bahamense</i>  | 2525 MU 100 g <sup>-1</sup>  | 5 human fatalities;<br>8 cases of PSP  | Malaysia  | Sang and Ming (1984);<br>Ming and Wong (1989);<br>Kan et al. (1986)                                   |
| <i>Polinices duplicata</i><br><i>Thais haemastoma</i>  | <i>Gonyaulax monilata</i>  | Not given  | Snail mortalities  | Texas   | Wardle et al. (1974)  |
| Tekuyong   | <i>Pyrodinium</i><br><i>bahamense</i>  | 71–876 MU 100 g <sup>-1</sup>  |  | Borneo  | Jaafar and Sburamaniam<br>(1984); Jaafar et al.<br>(1989)   |

|                                |                              |   |                         |                               |   |
|--------------------------------|------------------------------|---|-------------------------|-------------------------------|---|
| <i>Lunatia heros</i>           | <i>A. tamarense</i>          | 247   |                         | Gulf of St. Lawrence, Canada  | Worms et al. (1993)   |
| <i>Lambis lambis</i>           | <i>Pyrodinium bahamense</i>  | ND-175 MU 100 g <sup>-1</sup><br>very toxic | Several cases of PSP    | Sabah, Malaysia               | Sang and Ming (1984)<br>Ming and Wong (1989)  |
| <i>Nassarius</i> sp.           | Probably <i>A. catenella</i> | 9   | Scavengers              | Washington                    | Beitler (1992)  |
| <i>Buccinum undatum</i>        | <i>A. tamarense</i>          | 3337  | Illnesses and deaths    | Gulf of Maine, USA            | White et al. (1993);<br>Prakash et al. (1971);<br>Hurst (unpublished);<br>Bond (1975) |
| <i>Euspira heros</i>           |                              | 2922  |                         |                               |   |
| <i>Neptunea decemcostata</i>   |                              | 1060  | Steamed; ~3000-4000 raw |                               |   |
| <i>Crepidula fornicata</i>     |                              | 46-58                                       |                         |                               |   |
| <i>Colus stimpsoni</i>         |                              | Toxic                                       |                         |                               |   |
| <i>Thais lapillus</i>          |                              | Toxic                                       |                         |                               |   |
| <i>Polinices lewisii</i>       | <i>G. acatenella</i>         | 176-600                                     | Not specified           | British Columbia              | Quayle (1969);<br>Matter (1993)   |
| <i>Thais lamellosa</i>         | <i>A. catenella</i>          | Positive                                    | Whole snails            | Washington                    | MacDonald (1970)  |
| <i>T. lima</i>                 |                              | 180   | Whole snails            |                               |   |
| <i>Thais</i> sp.               |                              | 23  | GTX 2 + 3 only          |                               | Beitler (1992)  |
| <i>Neptunea</i> spp.           | <i>A. catenella</i>          | 200-250                                     | Whole individuals       | Alaska                        | Matter (1993)   |
| <i>Argobuccinum</i> sp.        | <i>A. catenella</i>          | 5629  | Stomach                 | Chile                         | Uribe (1995)  |
|                                |                              | 92  | Muscle                  |                               |   |
| <i>Adelamelon ancilla</i>      |                              | Toxic                                       |                         |                               |   |
| <i>Trophon</i> sp.             |                              | Toxic                                       |                         |                               |   |
| <i>Concholepas concholepas</i> |                              | Toxic                                       |                         |                               |   |
| <i>Busycon</i> spp.            | <i>A. tamarense</i>          | 50-500                                      | Not specified           | Quebec                        | Matter (1993)   |
| <i>Nassarius</i> sp.           | <i>Prorocentrum minimum</i>  | 1820-1890 MU 100 g <sup>-1</sup>            | Many human fatalities   | Zhengjiang and Fuziang, China | Chen and Gu (1993)  |

TABLE 1 (continued)  
**A Summary of Phycotoxins and Tetrodotoxins (TTX) Associated with Gastropod Molluscs. Maximum Recorded Values are Given. Species Names are as Given in Original Publications**

| Gastropod species <sup>a</sup>                          | Toxin Source <sup>b</sup>                       | Toxin Level <sup>c</sup>                          | Notes                                 | Location | Ref.   |
|---|---|---|---------------------------------------|----------|--|
| <i>Zeuxis siquijorensis</i>                             | Tetrodotoxin                                    | 3.4 MU g <sup>-1</sup>                            | Edible parts                          | Japan    | Narita et al. (1984)   |
| <i>Niotha clathrata</i>                                 | Tetrodotoxin                                    | 35 MU g <sup>-1</sup>                             | Edible parts                          | Japan    | Jeon et al. (1984)   |
| <i>Natica lineata</i>                                   | Tetrodotoxin<br>Anhydrotetrodotoxin             | 12 MU g <sup>-1</sup><br>720 MU g <sup>-1</sup>   | Digestive gland<br>Muscle             | Taiwan   | Hwang et al. (1990)  |
| <i>Rapana rapiformis</i><br><i>Rapana venosa venosa</i> | Tetrodotoxin                                    | 140 MU g <sup>-1</sup><br>13 MU g <sup>-1</sup>   | Digestive gland<br>Digestive gland    | Taiwan   | Hwang et al. (1991)  |
| <i>Charonia sauliae</i><br><i>Babylonia japonica</i>    | Tetrodotoxin from<br>starfish and<br>pufferfish | 1950 MU g <sup>-1</sup><br>180 MU g <sup>-1</sup> | Illnesses and<br>deaths               | Japan    | Shiomi et al. (1984);<br>Noguchi et al. (1981a),<br>1992); Narita et al. |
| (1981);<br><i>Tutufa lissostoma</i>                     |   | 700 MU g <sup>-1</sup>                            | Digestive glands/<br>toxic year round | Japan    | Yasumoto et al. (1981);<br>Noguchi et al. (1984)                         |

<sup>a</sup> *Euspira heros* = *Lunatia heros* = *Polinices heros*; *Thais* = *Nucella*.  
<sup>b</sup> *Alexandrium tamarense* (= *Gonyaulax tamarensis* = *Protogonyaulax tamarensis* = *Gonyaulax excavata*); *A. catenella* (= *Gonyaulax catenella* = *Protogonyaulax catenella*); *G. monilata* (= *Alexandrium monilata*); all taxonomic names are as in original publications.  
<sup>c</sup> Unless otherwise specified, toxin level is given in µg STX equiv/100 g tissue.

TABLE 2

**A Summary of Phycotoxins and Tetrodotoxins Associated with Crustaceans. Maximum Recorded Values are Given. Species Names Are as Given in Original Publications**

| Crustacean species                   | Toxin source <sup>a</sup>                                     | Toxin level <sup>b,c</sup>                    | Notes  | Location                          | Ref.   |
|--------------------------------------|---|---|--|-----------------------------------|--|
| <b>Crabs</b>                         |   |   |  |                                   |  |
| <i>Actaeodes tomentosus</i>          | <i>Jania</i> sp. (?)  | 5.9 MU g <sup>-1</sup>                        | Human illnesses and mortalities                                  | Japan                             | Yasumoto et al. (1981, 1983); Hashimoto et al. (1967); Inoue et al. (1968); Kotaki et al. (1983); Noguchi et al. (1969; 1983a,b); Mote et al. (1970) |
| <i>Atergatis floridus</i>            |   | 9000 MU g <sup>-1</sup>                       |  |                                   |  |
| <i>Eriphia scabricula</i>            |   | 120 MU g <sup>-1</sup>                        |  |                                   |  |
| <i>Neoxanthias impressus</i>         |   | 10 MU g <sup>-1</sup>                         |  |                                   |  |
| <i>Percnon planissimum</i>           |   | 7.4 MU g <sup>-1</sup>                        |  |                                   |  |
| <i>Pilumnus vespertilio</i>          |   | 6.1 MU g <sup>-1</sup>                        |  |                                   |  |
| <i>Platypodia granulosa</i>          |   | 5000 MU g <sup>-1</sup>                       |  |                                   |  |
| <i>Schizophrys aspera</i>            |   | 2.3 MU g <sup>-1</sup>                        |  |                                   |  |
| <i>Thalamita</i> sp.                 |   | 80 MU g <sup>-1</sup>                         | Highly variable Appendages Cephalothorax Whole body (calculated) | Ishigaki Island                   | Koyama et al. (1983); Konosu et al. (1970)   |
| <i>Zosimus aeneus</i>                |   | 16500 MU g <sup>-1</sup>                      |  |                                   |  |
|                                      |   | 2000 MU g <sup>-1</sup>                       |  |                                   |  |
|                                      |   | 800 MU g <sup>-1</sup>                        |  |                                   |  |
|                                      |   | 1260 MU g <sup>-1</sup>                       |  |                                   |  |
| <i>Portunus pelagicus</i>            | <i>Pyrodinium bahamense</i>                                   | 175 MU 100 g <sup>-1</sup>                    | Whole crab   | Sabah, Malaysia                   | Sang and Ming (1984)   |
|                                      |   | 288 MU g <sup>-1</sup>                        | Gills  |                                   |  |
|                                      |   | 328 MU g <sup>-1</sup>                        | Guts   |                                   |  |
|                                      |   | ND  | Flesh  |                                   |  |
| <i>Cancer magister</i>               | <i>Gonyaulax catenella</i>                                    | 72  | Viscera  | Washington                        | Washington Dept. Soc. Health Services (1980)   |
| <i>Cancer irroratus</i>              | <i>Gonyaulax tamarensis</i>                                   | 242   | Hepatopancreas   | Laboratory study; fed toxic clams | Foxall et al. (1979)   |
| <i>Cancer productus</i>              | <i>Gonyaulax catenella</i>                                    | 285<br>ND-27                                  | Viscera<br>Muscle  | Washington                        | Jonas Davies and Liston (1985)   |
| <i>Cancer borealis</i>               | <i>Gonyaulax tamarensis</i>                                   | 56  | Not specified  | Maine                             | Goggins (1961)   |
| <i>Cancer magister</i><br>stone crab | <i>Pseudonitzschia</i><br><i>P. delicatissima</i><br>Others ? | 485 ppm DA <sup>a</sup><br>176 ppm<br>105 ppm | Viscera<br>Gut<br>Body meat                                      | Pacific Coast,<br>USA             | Villac et al. (1993); Anonymous (1992); DFO (1992); Wekell et al. (1995)   |

|  |                             |  |   |                   |  |
|--|-----------------------------|--|---|-------------------|--|
| <i>Fabia subquadrata</i>                                   | <i>Gonyaulax catenella</i>  | 32   | Whole crabs;<br>commensal in butterclams                        | Washington        | MacDonald (1970)   |
| <i>Pagurus</i> sp.   | <i>Gonyaulax catenella</i>  | 35   | Whole crabs   | Washington        | MacDonald (1970)   |
| <i>Pugettia producta</i>                                   | <i>Gonyaulax catenella</i>  | 146<br>1710<br>48  | Eggs<br>Viscera<br>Muscle                                       | Maine             | Goggins (1961)   |
| <i>Hemigrapsus oregonensis</i><br><i>Hemigrapsus nudus</i> | <i>Gonyaulax catenella</i>  | 32<br>44   | Not specified<br>Whole bodies, legs<br>and carapace removed     | Washington        | Jonas-Davies and Liston<br>(1985); Barber et al. (1988);<br>MacDonald (1970) |
| <i>Emerita analoga</i>                                     | <i>Gonyaulax</i> sp.        | >60 mg <sup>d</sup><br>250 mg<br>10 mg                         | Filter-feeder; whole crab<br>Viscera<br>Muscles                 | California        | Sommer (1932)  |
| Crab   | <i>Pyrodinium bahamense</i> | 339 MU 100 g <sup>-1</sup>                                     | Not specified   | Brunei Darussalam | Jaafar and Subramaniam   |
| <i>Lophozozymus pictor</i>                                 | Unknown                     | 18.9 MU g <sup>-1</sup><br>0.3 MU g <sup>-1</sup>              | Homogenized crabs<br>Moult                                      | Australia         | Llewellyn and Endean (1989)  |
| <i>Thalamita stimpsoni</i>                                 | Unknown                     | 4.9 MU g <sup>-1</sup>   | Whole crabs   | Australia         | Llewellyn and Endean (1987)  |
| <i>Atergatis floridus</i>                                  | Tetrodotoxin                | Not specified  | STX/neoSTX also<br>present; first record<br>of TTX in arthropod | Japan             | Noguchi et al. (1984);<br>Noguchi et al. (1983)                              |
| Mangrove crabs   | <i>Pyrodinium bahamense</i> | 239 MU 100 g <sup>-1</sup><br>175 MU 100 g <sup>-1</sup><br>ND | Guts<br>Gills<br>Flesh  | Sabah, Malaysia   | Sang and Ming (1984)   |

TABLE 2 (continued)

**A Summary of Phycotoxins and Tetrodotoxins Associated with Crustaceans. Maximum Recorded Values are Given. Species Names Are as Given in Original Publications**

| Crustacean species          | Toxin source <sup>a</sup>                                     | Toxin level <sup>b,c</sup>  | Notes  | Location                                       | Ref.  |
|-----------------------------|---|---|--|--|---|
| <b>LOBSTERS</b>             |   |   |  |  |   |
| <i>Panulirus versicolor</i> | <i>Pyrodinium bahamense</i>                                   | 175 MU 100 g <sup>-1</sup><br>175 MU 100 g <sup>-1</sup><br>ND MU 100 g <sup>-1</sup> | Whole lobster<br>Body only<br>Tail only  | Sabah, Malaysia                                | Sang and Ming (1984)                              |
| <i>Panulirus longipes</i>   | <i>Pyrodinium bahamense</i>                                   | 211 MU 100 g <sup>-1</sup><br>177 MU 100 g <sup>-1</sup><br>ND                        | Whole lobster<br>Head and legs<br>Tail only  | Sabah, Malaysia                                | Sang and Ming (1984)                              |
| <i>Homarus americanus</i>   | <i>Gonyaulax tamarensis</i>                                   | 60<br>3<br>21   | Hepatopancreas<br>Tail muscle<br>Appendage muscle  | Laboratory study;<br>fed toxic clams           | Foxall et al. (1979)                              |
| <i>Homarus americanus</i>   | <i>Alexandrium tamarense</i>                                  | 429<br>110  | Hepatopancreas (raw)<br>Hepatopancreas (cooked);<br>lobsters fed toxic scallops<br>in laboratory | Gulf of Maine                                  | Sherman (unpublished)                             |
|                             |   | 124<br>64   | Hepatopancreas (raw)<br>Hepatopancreas (cooked);<br>mean values (n=20)                           | Nova Scotia                                    | Watson-Wright et al.<br>(1991)                    |
| <i>Homarus americanus</i>   | <i>Alexandrium tamarense</i>                                  | 1854<br>540<br>ND   | Hepatopancreas (raw)<br>Hepatopancreas (cooked)<br>Muscle  | Cutler, Maine                                  | Hurst (unpublished)                               |
| <i>Homarus americanus</i>   | <i>Alexandrium tamarense</i>                                  | 1512<br>961<br>69   | Hepatopancreas<br>(bioassay)<br>Hepatopancreas (HPLC)<br>Meat (HPLC)                             | Bay of Gaspé,<br>Canada                        | Desbiens and Cembella<br>(1995)                   |
| <i>Homarus americanus</i>   | <i>Alexandrium tamarense</i>                                  | 275-3200<br>ND  | Hepatopancreas<br>Tail muscle  | Laboratory study; fed<br>toxic scallop viscera | Haya et al. (1992)                                |
| Spiny lobster               | <i>Pseudonitzschia</i><br><i>P. delicatissima</i><br>Others ? | 12 ppm DA <sup>d</sup>  | Gut  | Pacific Coast, USA                             | DFO (1992); Villac et al.<br>(1993); Anon. (1992) |

|                                     |                             |  |  |                   |                               |
|-------------------------------------|-----------------------------|--|--|-------------------|-------------------------------|
| <b>SHRIMP</b>                       |                             |  |  |                   |                               |
| Penaeidae                           | <i>Pyrodinium bahamense</i> | 175 MU 100 g <sup>-1</sup><br>268 MU 100 g <sup>-1</sup> | Frozen tails for export<br>Body only                               | Sabah, Malaysia   | Sang and Ming (1984)          |
| Penaëid prawn                       | <i>Pyrodinium bahamense</i> | 190 MU 100 g <sup>-1</sup>                               | Not specified  | Brunei Darussalam | Jaafar and Subramaniam (1984) |
| <b>HORSESHOE CRAB</b>               |                             |  |  |                   |                               |
| <i>Carcinoscorpius rotundicauda</i> | Unknown (resembles STX)     | 25 MU 100 g <sup>-1</sup>                                | Exoskeleton, muscle  | Thailand          | Fusetani et al. (1982)        |
|                                     |                             | 65 MU 100 g <sup>-1</sup>                                | Eggs   |                   |                               |
|                                     |                             | 75 MU 100 g <sup>-1</sup>                                | Hepatopancreas   |                   |                               |
|                                     |                             | 10 MU 100 g <sup>-1</sup>                                | Stomach and contents   |                   |                               |
|                                     |                             | 85 MU 100 g <sup>-1</sup>                                | Gills  |                   |                               |
|                                     |                             | 50 MU 100 g <sup>-1</sup>                                | Coelomic fluid   |                   |                               |
|                                     | Tetrodotoxin                | 35 MU 100 g <sup>-1</sup><br>16 MU g <sup>-1</sup>       | Tail<br>Eggs; some STX/<br>neoSTX also present;<br>human illnesses | Gulf of Thai      | Kungsuwan et al. (1987)       |
|                                     | Tetrodotoxin                | 65 MU g <sup>-1</sup>                                    | Hepatopancreas   | Thailand          | Saltanu et al. (1987)         |

\* *Alexandrium tamarense* (= *Gonyaulax tamarensis* = *Protogonyaulax tamarensis*); *A. catenella* (= *Gonyaulax catenella* = *Protogonyaulax catenella*); *Pseudonitzschia* (= *Nitzschia*). All taxonomic names are as in original publications.

<sup>b</sup> Unless otherwise specified, toxin level is given in µg STX equivalent/100 g tissue.

<sup>c</sup> Note: domoic acid concentrations.

<sup>d</sup> Average lethal dose (to mice) of extracts.