# Investigations into the Introduction of Non-indigenous Marine Organisms via the Cross-Continental Trade in Marine Baitworms

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## Introduction

Two species of marine polychaetes, *Nereis virens* Sars[1] ("pileworms"[2]) and *Glycera dibranchiata* Ehlers ("bloodworms"[3]), are imported into California in large numbers from the U.S. East Coast to be sold as fishing bait. The worms arrive by air freight, in shallow cardboard boxes packed with Atlantic coastal seaweeds, primarily *Ascophyllum nodosum* (Linnaeus) Le Jolis. Other living algae, fungi, invertebrates and protozoans from the Atlantic coast have been found in these boxes after their arrival in California, and a significant portion of these exotic organisms are regularly released into the California marine environment, where a few have apparently become established. The goal of this project is to provide a qualitative and quantitative assessment of the diversity and abundance of non-indigenous marine organisms imported and released into San Francisco Bay via the trade in marine baitworms. This project builds on two previous studies by report co-authors.

## Previous Work

In Carlton (1979, 1992), JTC reported on the organisms he identified in the seaweed packing of baitworms shipped from U.S. East Coast to Newport Bay in southern California. These include three common New England periwinkles, the bay mussel *Mytilus edulis*, isopods, gammarid amphipods, and a marine ascomycete (fungus) growing on the algae.

In Lau (1995), WL reported on organisms identified in samples of baitworms and seaweed packing shipped from the U.S. East Coast to the San Francisco Bay Area, and on information gleaned from interviews of bait dealers in Maine and bait shops and anglers in the Bay Area. The most common organisms found include many of those reported by Carlton, plus Halacaridae (marine mites) and copepods.

## Methods

(A) Qualitative sampling of organisms shipped with marine baitworms
From 1995-1998, ANC, MAE and AW examined baitworm shipping boxes at baitshops in the greater San Francisco Bay Area. These boxes ranged from freshly-arrived, undisturbed boxes with contents in good condition, to boxes that were several days to a week post-arrival, from which some portion of the worms and seaweed packing had been removed for sale, and with the worms in poor condition or dead and decaying. We examined the boxes on-site, collecting all organisms other than *Nereis virens*, *Glycera dibranchiata* and *Ascophyllum nodosum* and fixing them in either formalin, 70% ethanol, or 70% isopropanol. We identified the organisms in the laboratory under stereo or compund microscopes as needed to lowest possible taxon, and preserved them in 70% ethanol. We counted or noted the level of abundance of organisms in each taxon. These samples were intended as primarily qualitative samples, since the large variations in the age and state of the shipping boxes and in the effort put into examining them made it impossible to make effective use of this data to estimate the number of arriving organisms.

(B) Quantitative sampling of organisms shipped with marine baitworms
From August to October 1998, AW sampled the seaweed packing in baitworm shipping boxes at baitshops in the San Francisco Bay Area. At the time that they were sampled, the boxes had been stored (refrigerated) in the baitshops for a maximum of 48 hours. For freshly-arrived, undisturbed

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1 Called *Neanthes virens* by some authors.

2 Called "pileworms" on the U.S. West Coast, "sandworms" or "clamworms" on the U.S. East Coast and "ragworms" in Europe.

3 Also called "beakworms" on the U.S. East Coast.

boxes, she weighed the full box with worms and seaweeds, the worms and seaweed alone, and the seaweed alone. From all boxes, 30-150 gram samples of seaweed were removed for transport to the laboratory. The remaining seaweed was then examined as qualitative samples, as described above.

All seaweed samples were refrigerated and analyzed within 24 hours. From each sample, 20-gram subsamples were taken and examined for 1-2 minutes for epiphytic organisms, algae, or egg masses. The subsamples were then submerged and shaken in a pan of cold tap water to release organisms, then removed from the water. The water was allowed to stand for 5 minutes, and organisms and other small material that settled to the bottom were removed by pipette. The seaweed subsamples and pipetted material were then examined under a stereo-microscope for sorting and initial identification by AW, and the organisms were preserved in 70% ethanol. Final identification was done by ANC and JTC in January-February 1999, in consultation as needed with experts in specific taxonomic groups.

(C) Re-examination of samples from prior study
In 1994-1995, WL collected and identified organisms in samples of marine baitworms and seaweed packing as her senior thesis project in Environmental Sciences at University of California, Berkeley, for which ANC and JTC served as external advisors. In January-February 1999, ANC re-examined the organisms preserved from this study to confirm or refine the identifications, consistent with the work done on the 1998 samples.

(D) Investigations in Maine
In 1996 ANC visited and interviewed bait dealers in Wiscasset, Maine and researchers who had worked on the baitworm fishery, for information on the handling practices, history and scale of the trade in baitworms and seaweed packing from Maine.

(E) Survey of baitworm importing
In 1997 MAE conducted a telephone survey of baitshops and bait distributors in the San Francisco Bay Area to assess the quantity, seasonal pattern and trends of imports of marine baitworms from the U.S. East Coast.

## Results and Discussion

The Maine Baitworm Fishery
The commercial fishery for marine baitworms is the fourth or fifth most valuable fishery in the State of Maine (Dow and Creaser 1970; Creaser *et al.* 1993), accounting for 90% of the baitworm fisheries in the United States (Brown 1993). The fishery harvests two species of polychaete worms, the pileworm *Nereis virens* Sars and the bloodworm *Glycera dibranchiata* Ehlers. The reported native range of *Nereis virens* includes both sides of the Atlantic, from the Maritime provinces of Canada from as far north as Labrador south to Virginia, and from Iceland, Ireland, Norway and the Russian White Sea south to France (Creaser *et al.* 1983; Brown 1993). It has also been reported from Japan (Yokouchi 1985, cited in Brown 1993). The reported native range of *Glycera dibranchiata* includes both the northwestern Atlantic from Prince Edward Island and Nova Scotia to Florida, along the Gulf of Mexico to Texas, and the West Indies, and the northeastern Pacific from San Mateo County in California to Mazatlan in Mexico (Creaser *et al.* 1983).[4]

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[4] Since the larvae of *Glycera dibranchiata* have never been found in the water column, they presumably spend little time as plankton and are poor dispersers (Vadas and Bristow 1985); and consistent with this, Bristow (1983, cited in Vadas and Bristow 1985) found significant genetic differentiation indicating limited gene flow between local populations in estuaries around the Gulf of Maine. This suggests that a genetic analysis would classify the Atlantic and Pacific populations of *Glycera dibranchiata* as separate species.

A small fishery for these worms started on Long Island, New York in 1921-22, and expanded during the Depression to include the Massachusetts coast north of Boston. In 1993 a large stock of worms was discovered in Boothbay Harbor, Maine in the vicinity of Wiscasset, which quickly became the center of the fishery. In 1937 the Maine Legislature passed its first marine baitworm law, requiring the licensing of worm diggers. A number of restrictive laws were adopted by the state or municipalities from 1937 to 1955, which appear to have been passed in order to protect coastal properties against trespass rather than to manage the fishery. These laws were repealed in 1955 (Creaser *et al*. 1983).

Our investigations indicated that most or all of the marine baitworms imported into California originated from Maine, primarily from the Wiscasset/Boothbay Harbor region, although there has also been a marine baitworm fishery in Canada's Atlantic provinces (Creaser *et al*. 1983; P. Shepherd, pers. comm. 1997).[5] The National Marine Fishery Service and the Maine Department of Marine Resources compile annual data on total landings of baitworms in Maine (in numbers of worms and converted to pounds) and their wholesale value (Creaser *et al*. 1991; Brown 1993), and the State of Maine keeps track of the number of licensed baitworm diggers, seaweed gatherers and baitworm dealers. The number of diggers and the number of worms landed grew from the 1950s to the mid-1970s, then declined, while the dollar value of the fishery has steadily increased (Table 1). There were 94 licensed seaweed gatherers in the baitworm trade in 1991, and 36-52 licensed baitworm dealers each year from 1966 (when licenses were first required) to 1991 (Brown 1993).

**Table 1. Some statistics on the Maine marine baitworm fishery**

Data from Creaser *et al*. (1983) and Brown (1993). Dollar figures are apparently not adjusted for inflation.

| Decade | Number of licensed worm diggers | Number of pileworms harvested per year | Number of bloodworms harvested per year | Annual value of landings |
|---|---|---|---|---|
| 1950s | 300-800 | 2-25 million | 3-25 million | $ 0.1-0.8 million |
| 1960s | 800-1200 | 26-33 million | 26-37 million | $ 0.9-1.8 million |
| 1970s | 1000-1450 | 28-33 million | 16-36 million | $ 2.0-2.8 million |
| 1980s | 800-1000 | 14-32 million | 17-29 million | $ 2.7-4.0 million |

## Marine Baitworms Imported into California

While information on the Maine fishery as a whole is readily available, there appears to be virtually no information available from government agencies in either Maine or California on the annual quantities or value of pileworms and bloodworms shipped as live fishing bait from Maine to California. The State of California appears to have no official knowledge of the fact that the marine baitworms sold in the state come from the Atlantic Coast.[6]

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5 One Bay Area baitshop told WL that they had received some pileworms from New York and another said that they get shipments from Boston, although it's unclear whether these were the points of origin or transhipment points.

6 For example, Collins (1992) reported that other than the importing of oyster seed for aquaculture, the only importing of live marine organisms allowed by California outside of ICES guidelines was the "interstate movement of species within their established range from other west coast states," citing as examples the shipment of "ghost and mud shrimps (genera *Callianassa* and *Upogebia*) and marine annelid worms (Phylum Annelida), between west coast states for use as marine baits." However, as discussed in the text, nearly all the marine annelid worms sold in California baitshops come from the U.S. Atlantic coast, a few come from Southeast Asia, and none appear to come from west coast states. Under California law, either a Standard Importation Permit or a Long

Accordingly, we assembled information on the importing of baitworms by interviewing bait dealers in Maine, and bait distributors and baitshop operators in the Bay Area. We interviewed, by telephone or in person, a few bait dealers in Maine, focusing on dealers whom we knew had shipped worms to California. These interviews indicate that these few dealers have shipped about 7,400 to 8,500 boxes per year of pileworms and bloodworms to the Bay Area in recent years (Table 2).

**Table 2. Baitworms shipped to San Francisco Bay Area by Maine baitworm dealers**

| Dealer | Date / Interviewer | Comments |
|---|---|---|
| #1 | 1994 / WL<br>1996 / ANC | Ships about 2,000 boxes/yr of pileworms and 2,000 boxes/yr of bloodworms to Bay Area. Used to also ship to Sacramento. |
| #2 | 1996 / ANC | Was the first to ship to California, starting around 1963-64. Now retired. |
| #3 | 1998 / AW | Shipped 5,000-6,000 boxes/yr of worms to Bay Area since 1972. The highest volume is in the spring, and the volume is increasing. |
| #4 | 1998 / AW | Shipped 400-500 boxes/yr of worms to Bay Area since 1996. Ships more pileworms in the spring, more bloodworms in summer and fall. |
| #5 | 1998 / AW | No shipments for last 2 years due to shortage of worms. |
| #6 | 1998 / AW | Began shipping worms to Bay Area about 20 years earlier, but not for the past 3 years due to shipping problems (worms arriving in poor condition because of fewer direct flights). |

Bay Area bait distributors are listed in Appendix 1. None of the distributors we contacted were willing to provide information about the quantities of baitworms they imported.

Most of our interview effort went into a comprehensive survey of Bay Area baitshops (conducted by MAE in 1997). For these interviews we prepared a list of questions (Appendix 2) regarding the numbers and types of baitworms imported and sold, the history, seasonal patterns and trend over time of this trade, and information on what the baitshops did with the seaweed used to pack the worms for shipment. From the Yellow Pages covering the greater Bay Area (Appendix 3), we compiled a list of 103 enterprises listed under "Fishing Bait" (Appendix 4). Three of these were wholesale bait dealers (" bait distributors"), leaving 100 listed baitshops. Nine of these had disconnected telephone numbers with no new number provided. We contacted 78 shops, of which 5 declined to participate. Of the 73 respondents, 41 sold marine baitworms. The data for these are shown in Table 3, and summarized in Table 4.

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Term Importation Permit are required to import live marine annelids into the state (Title 14, California Code of Regulations, Section 236. *Importation of Live Aquatic Plants and Animals*); however, in 1997 when we asked the California Department of Fish and Game for a list of the holders of importation permits for marine annelids, we were informed that there were no current permits (R. Collins, pers. comm. 1995).

**Table 3. Baitshop survey data**

| Pile-worms | Blood-worms | High season period | High season imports (bx/wk) | Low season imports (bx/wk) | Annual imports (bx/yr) | Years since start of trade | Trend of sales over time | Provides seaweed to customers? |
|---|---|---|---|---|---|---|---|---|
| Yes | Yes | • | • | • | • | • | • | • |
| Yes | Yes | Mar-Apr | • | • | • | 10 | 0 | Yes |
| Yes | No | Mar-May | • | • | 5 | • | • | • |
| Yes | Yes | Apr-Jun | 0.33 | 0.33 | 18 | 30 | 0 | Yes |
| Yes | No | Mar-May | 1 | 0.33 | 26 | 35 | • | Yes |
| Yes | Yes | Mar-May | • | • | 30 | 15 | • | Yes |
| Yes | No | Apr-Jul | 2 | 0 | 36 | 5 | 0 | Yes |
| Yes | Yes | Feb-Aug+ | 1 | 0 | 38 | 2 | – | On Req |
| Yes | No | May-Jul | 2 | 0.5 | 46 | 20 | – | Yes |
| No | Yes | • | 1 | 1 | 50 | 1 | • | No |
| Yes | No | Sep-Oct, Mar-May | 1 | 1 | 52 | 11 | 0 | Yes |
| Yes | Yes | Nov-Jan | 1 | 1 | 52 | 10 | 0 | Yes |
| Yes | Yes | May-Aug | 2 | 1 | 70 | 1 | 0 | Yes |
| Yes | Yes | Feb-Aug | 2 | 1 | 74 | 15 | 0 | Yes |
| Yes | No | Mar-Aug | 3 | 0.5 | 91 | 8 | – | Yes |
| Yes | No | Apr-Jul | 4.5 | 0.5 | 95 | 1 | + | Yes |
| Yes | Yes | Mar-Jun | 2 | 2 | 104 | 7 | 0 | Yes |
| Yes | No | Mar-Jul | 2 | 2 | 104 | 4 | – | Yes |
| Yes | No | Nov-Jan | 2 | 2 | 104 | • | • | Yes |
| Yes | No | Nov-Jan | 2 | 2 | 104 | 7 | 0 | On Req |
| Yes | Yes | Nov-Jan | 2 | 2 | 104 | 30 | • | On Req |
| Yes | Yes | May-Sep | 2 | 1 | 110 | 32 | • | Yes |
| Yes | Yes | May-Aug | 3 | 2 | 122 | • | 0 | Yes |
| Yes | Yes | May-Aug | 5 | 1 | 124 | 5 | 0 | Yes |
| Yes | Yes | May-Jul | 2.5 | 2.5 | 130 | 10 | 0 | Yes |
| Yes | Yes | May-Sep | 5 | 1 | 140 | 23 | • | Yes |
| Yes | Yes | May-Jul | 5 | 2 | 146 | 8 | – | Yes |
| Yes | Yes | May-Jul | • | • | 150 | 7 | • | Yes |
| Yes | Yes | Jun-Sep | 6.5 | 1 | 151 | 35 | • | Yes |
| Yes | Yes | Seasonal | 3 | 3 | 156 | 15 | + | Yes |
| Yes | Yes | Feb-Jun | 5 | 2 | 170 | 24 | – | Yes |
| Yes | Yes | Mar-May+ | 7 | 2 | 194 | 25 | – | Yes |
| Yes | Yes | Mar-Nov | 5 | 2 | 209 | 6 | • | Yes |
| Yes | Yes | Mar-May | 10 | 7 | 244 | 20 | 0 | Yes |
| Yes | Yes | Mar-May | 20 | 0 | 260 | 18 | – | No |
| Yes | Yes | Sep-Jan | 5 | 5 | 260 | 6 | + | Yes |
| Yes | Yes | Nov-Jan | 5 | 5 | 260 | 15 | 0 | Yes |
| Yes | Yes | Aug-Oct | 5 | 4 | 316 | 35 | + | Yes |
| Yes | Yes | Mar-Aug | 4.5 | 12.5 | 442 | 12 | • | Yes |
| Yes | Yes | Apr-Aug | • | • | 450 | 25 | + | Yes |
| Yes | Yes | Mar-Jun | 14 | 7 | 490 | 32 | – | Yes |

**Table 4. Summary of survey responses**

| Baitshop Category | # | Relevant percentages |
|---|---|---|
| Listed in Bay Area yellow pages | 100 | – |
| Disconnected telephone number | 9 | – |
| Contacted | 78 | 78% of Listed shops |
| Declined to Answer | 5 | 6% of Shops contacted |
| Responded | 73 | 94% of Shops contacted |
| Carries Bloodworms or Pileworms | 41 | 56% of Shops that responded |
| Pileworms only | 40 | 55% of Respondents, 98% of Shops selling worms |
| Bloodworms only | 31 | 42% of Respondents, 76% of Shops selling worms |
| Answered question on Annual Imports | 39 | 95% of Shops selling worms |
| Answered question on Sales Trend | 28 | 68% of Shops selling worms |
| Increasing ( + ) | 5 | 18% of Shops answering question |
| Stable ( 0 ) | 14 | 50% of Shops answering question |
| Decreasing ( – ) | 9 | 32% of Shops answering question |
| Answered question on Providing Seaweed | 39 | 95% of Shops selling worms |
| Provides to customers | 34 | 87% of Shops answering question |
| Provides when asked | 3 | 8% of Shops answering question |
| Does not provide | 2 | 5% of Shops answering question |

Of the shops that sell marine baitworms, nearly all (98%) sell pileworms and about three-quarters sell blood worms. On average, the shops had been selling these baitworms for 15 years. Nineteen percent of the shops that answered had sold these baitworms for more than 30 years, with the longest being about 35 years (i.e. since around 1962). This is consistent with the information from our interviews of Maine baitworm dealers, in which one dealer (recommended as a reliable source on the history of the trade) stated that baitworm shipments to California had begun around 1963-64. The published literature is less informative: the earliest reference we found to the start of the California trade was a statement by Creaser and Dow (1983) that it was "relatively new".

Creaser and Dow (1983) reported that there were two peak seasons for shipping baitworms from Maine to California, from February to May or June, and from September to November, with fewer worms shipped during the summer because of the risk of high mortalities during shipping due to high temperatures and flight delays. The bait dealers we interviewed in Maine confirmed that they have significant concerns about mortality during cross-country shipping, which have grown as the airlines implemented hub systems and direct flights from Boston to San Francisco became scarce. We graphed seasonality of baitworm commerce in the San Francisco Bay Area as the percentage of baitshops that list any particular month as part of the high season (Fig. 1). Sales of marine baitworms peak in March to June, but remain fairly high into August, and there is a very small late-fall peak.

From the interview data we estimated the number of boxes of baitworms shipped annually into the Bay Area. The 39 baitshops answering the question estimated that together they import 5,727 boxes of pileworms and bloodworms from the U.S. East Coast each year (Table 3, sum of Annual Imports column), most or all of which originated from Maine. Forty-one out of 73 responding shops carry imported marine baitworms, and there were 100 baitshops listed in the Bay Area yellow pages.[7] Multiplying, we obtain an estimate of :

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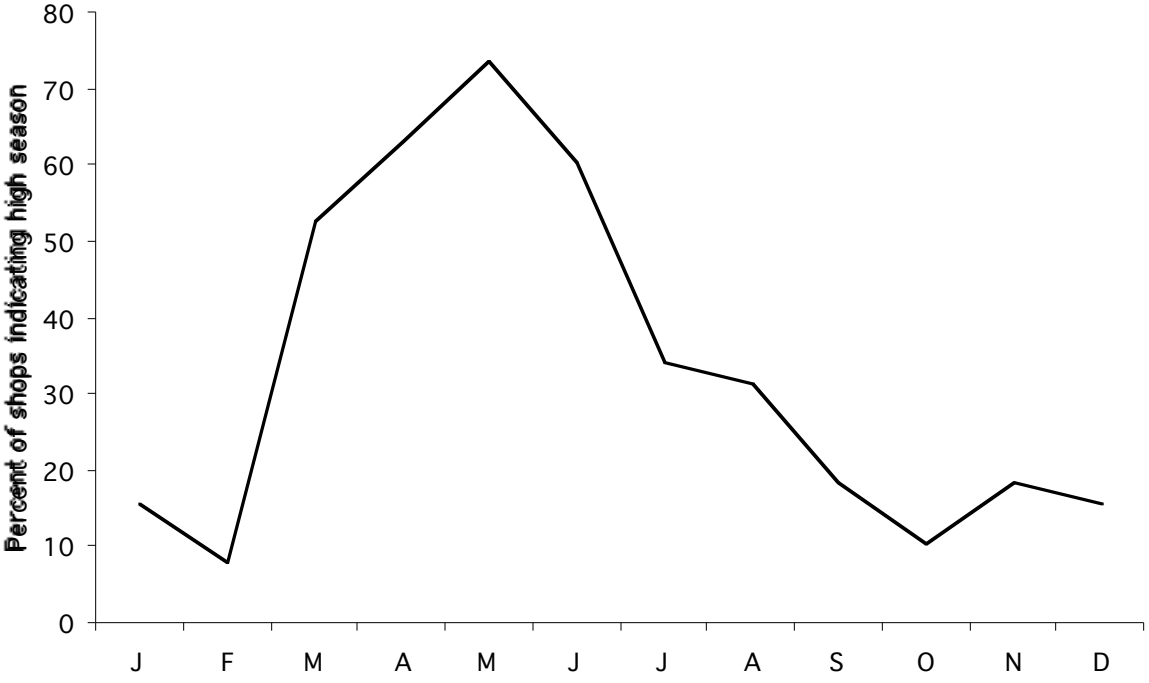
[7] The listed telephone numbers of 10% of the baitshops that we tried to reach had been disconnected and the telephone service did not provide forwarding numbers. Since some or most of these shops

**Figure 1. Seasonality of Baitworm Sales**




(5,727 ÷ 39) x (41 ÷ 73) x 100 = 8,250 boxes imported/year.

This agrees with our earlier estimate of 7,400 to 8,500 boxes per year currently being shipped to California by six baitworm dealers in Maine (Table 2). However, as there may be other Maine bait dealers shipping worms from Maine to the Bay Area, this latter range is likely to be an underestimate; since there are typically between 36 and 52 licensed Maine baitworm dealers in any given year (Brown 1993), it could be a substantial underestimate; but because we purposefully interviewed dealers whom we were told were the main shippers of baitworms to California, it may not be. In the end it may be fair to say that there are probably at least 8,000 boxes of pileworms or bloodworms shipped into the Bay Area in a typical year, and possibly a good deal more. In terms of trends, half of the responding shops felt their sales volume was stable, while about a third saw it as declining, and one-sixth said it was increasing.

Seaweed Imported with Baitworms

Baitshops in the San Francisco Bay Area typically sell marine baitworms by the dozen or half-dozen worms, usually packed in small cartons with some of the Atlantic seaweed that the worms had been shipped in from Maine. Our observations in Maine and California, the interviews we conducted with bait dealers and researchers in Maine, and most of the published literature (e.g. Pettibone 1963; Creaser *et al.* 1983) indicate that the seaweed used for packing consists almost

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had probably gone out of business this would tend to make our estimate an overestimate. On the other hand, we know of a couple of baitshops in the area that are not listed under "Fishing Bait" in the Yellow Pages, and any baitshops that had opened since the Yellow Pages were printed would also not be listed, and this would tend to make our estimate an underestimate.

entirely of the brown rockweed *Ascophyllum nodosum*,[8] although Carlton (1979, 1992) reported also finding another common Atlantic rockweed, *Fucus vesiculosus*, in the packing of marine baitworms shipped to Newport Bay, California, and Creaser *et al*. (1983) reported that the green seaweed *Ulva* sp., called sea lettuce, has sometimes been used for packing worms from Prince Edward Island in Canada, where *A. nodosum* is not available in suitable quantities. The native range of *A. nodosum* is from the Canadian Arctic to Delaware and from Russia to Portugal `(Schneider and Searles 1991).[9]

Most of the shops (87%) that we interviewed in 1997 sold baitworms packed in *Ascophyllum*, although a few did not and a few others provided seaweed when the customer asked for it. All four of the shops interviewed by Lau (1995) stated that they sold the baitworms pcked in seaweed, using all of the seaweed that arrived in the shipping boxes in the process.

To estimate the amount of seaweed imported, Lau (1995) purchased or received retail cartons of baitworms from Bay Area baitshops, each of which contained six worms and some seaweed packing. The mean weight of seaweed per six-worm carton was 44.3±19.5 (S.D.) g for pileworms (n = 4 cartons) and 46.0±2.8 g for bloodworms (n = 2). Assuming all the worms and seaweed in the shipping boxes are sold in such cartons,[10] these figures correspond to a mean weight of seaweed per shipping box of 923 g for pileworms, 1,917 g for bloodworms, and 1,255 g overall.[11] In 1998 we directly weighed the seaweed in shipping boxes that had recently arrived at Bay Area baitshops, and found the weight of seaweed per shipping box to average 1,158±378 g for pileworms (n = 5 boxes), 997±149 g for bloodworms (n = 4), and 1,118±291 g overall (n = 11) (Table 5). Combining both sets of measurements yields a mean weight of seaweed per shipping box of 1,166±414 g overall.

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8 Some authors have reported the seaweed packing to include both *A. nodosum* (sometimes as *A. nodosum* f. *scorpiodes*) and *A. mackaii* (sometimes spelled *mackii* or *machaii*) (e.g. Carlton 1979; Creaser *et al.* 1983; Brown 1993), but *mackaii* is now usually considered to be a form or ecophenotype of *A. nodosum* rather than a separate species.

9 *Ascophyllum nodosum* had occasionally been collected south of Delaware as far as North Carolina as loose drifting plants, but never as attached plants; however, it has now been found attached in at least three sites in North Carolina since 1976 (Humm 1979; Schneider and Searles 1991). This southward range extension may have resulted from *Acophyllum* shipped south with baitworms. Orris (1980) reported that *Ascophyllum* which was probably discarded bait-packing seaweed had been collected many times in Chesapeake Bay.

10 The assumption that all the baitworms and packing seaweed received by baitshops are sold to anglers is clearly not fully accurate. For example, as noted above we sometimes observed worms that were in poor condition or were dead and decaying in shipping boxes that had been received by the baitshops several days to a week earlier. These worms and often the seaweed they were contained in were likely discarded by the baitshops rather than sold to anglers. Where baitshops are located on piers over the water, this material might sometimes be discarded into the water along with any remaining living organisms; but in most cases it is probably discarded to a trash container and ultimated disposed of in a landfill. Thus this assumption probably leads to a modest overestimate of the amount of seaweed and number of organisms that are released into the water.

11 Recall that there are 125 pileworms or 250 bloodworms per shipping box. Bait dealers in Maine may use a different quantity or weight of seaweed per box when packing pileworms vs. bloodworms for shipment. It has been reported that some dealers prefer to use drier, lighter-colored, or coarser-textured *Ascophyllum* for packing pileworms than for packing bloodworms (Creaser *et al.* 1983).

**Table 5. Weight of seaweed per shipping box**

| Baitshop | Date | Worms | Weight of whole box (g) | Weight of worms & seaweed (g) | Weight of seaweed only (g) | Hours since delivery |
|---|---|---|---|---|---|---|
| #1 | 08/25/98 | pileworms | 2084 | 1476 | – | 3 |
| #1 | 10/12/98 | bloodworms | 2122 | 1610 | 1024 | 24 |
| #2* | 09/22/98 | ? | – | – | 1033 | 24-48 |
| #2* | 09/22/98 | pileworms | – | – | 1437 | 24-48 |
| #2* | 09/22/98 | ? | – | – | 1485 | 24-48 |
| #2* | 09/22/98 | pileworms | – | – | 1683 | 24-48 |
| #2* | 09/22/98 | pileworms | – | – | 918 | 24-48 |
| #3 | 09/24/98 | pileworms | 1912 | 1386 | 853 | 4 |
| #4 | 09/28/98 | bloodworms | 2186 | 1698 | 1152 | 24 |
| #4 | 09/28/98 | pileworms | 2075 | 1420 | 897 | 24 |
| #4 | 09/28/98 | bloodworms | 2061 | 1515 | 1017 | 24 |
| #4 | 10/05/98 | bloodworms | 1804 | 1235 | 794 | 2 |
| | | mean for pileworms: | 2024 | 1427 | 1158 | 23.2 |
| | | mean for bloodworms: | 2043 | 1515 | 997 | 18.5 |
| | | overall mean: | 2035 | 1477 | 1118 | 23.8 |

* Seaweed separated from worms by bait shop.

Organisms Imported in Seaweed Packing

Appendices 5 and 6 describe the qualitative and quantitative samples taken in this study. The taxa identified from these samples and in previous examinations of pileworm and bloodworm shipments arriving in California are listed in Appendix 7. These include at least 38 distinct species imported in addition to the baitworms and the seaweed used for packing, including one fungus, four algae and 30 invertebrates. Several invertebrates occurred frequently in these samples, including a sabellid worm (*Fabricia sabella*), three periwinkles, (*Littorina* spp.), a mussel (*Mytilus edulis*), four species of mites, three species of harpacticoid copepods, an isopod (*Jaera marina*) and an amphipod (*Hyale nilssoni*).

We estimated the number of baitworms and the amount of packing seaweed imported into the Bay Area each year based on our surveys, and then calculated the numbers of additional organisms imported and released into the Bay and nearby coastal waters, based on:

- the organisms' abundance in the quantitative samples taken in 1994-95[12] and 1998 (Appendix 8),
- an estimate of at least 8,000 boxes of marine baitworms shipped to the Bay Area each year (see text above),
- an estimate of an average of 1,166 grams of seaweed used as packing in each shipping box (see text above), and
- Lau's (1995) angler survey indicating that angler's discard at least 30% of the seaweed packing into the water or the intertidal zone.[13]

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12 Lau (1995) separately examined the baitworms and the seaweed packing for other organisms, and found a few small specimens of *Littorina obtusata, Hyale nilssoni* and a copepod adhered to the baitworms by secretions or surface tension. We did not include these in our main estimate of the number of organisms per shipping box.

In all, we estimate that over 700,000 pileworms and over 600,000 bloodworms are imported into the San Francisco Bay Area from the U.S. East Coast each year.[14] Although 40% of the anglers interviewed by Lau (1995) reported that they discarded their left-over baitworms into the water, we have no data on what fraction of the purchased bait is typically left over, and so cannot estimate how many end up in the Bay. However, it must be a significant number.[15]

As packing for these baitworms, over 9 metric tons of the Atlantic seaweed *Ascophyllum nodosum* are imported into the San Francisco Bay Area each year, of which nearly 3 metric tons are dumped into the Bay. We estimate that along with this seaweed more than a million invertebrates from the Atlantic Ocean (other than the baitworms themselves) are released into the Bay each year, including hundreds of thousands each of mites, amphipods and isopods, tens of thousands each of copepods, snails, mussels and polychaete worms, plus large numbers of nematode worms (Table 6).

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13 Lau interviewed 20 anglers who used marine baitworms how they disposed of their left-over worms and seaweed. Although the number of interviewees was small, our observations that on virtually any day one can collect clumps of fresh *Ascophyllum* along the shore near dozens of popular fishing sites on the Bay, or frequently find baitworm cartons containing *Ascophyllum* abandoned in the intertidal zone at many of these sites, suggests that the amount of *Acophyllum* discarded into the Bay is substantial.

14 To make these estimates we assumed that each baitshop that reported selling both pileworms and bloodworms imported an equal number of each; and then proceeded as we did above to extrapolate from the surveyed baitshops to all baitshops in the Bay Area.

15 As noted above in Footnote 4, the bloodworm *Glycera dibranchiata* is said to inhabit both coasts of North America, but its weak dispersing ability and the presence of detectable genetic differences between populations in the Gulf of Maine suggest that native populations in the Atlantic and Pacific are probably sufficiently distinct genetically to be considered separate species. We suggest that it would be worthwhile to examine the genetic structure of *G. dibranchiata* populations in San Francisco Bay and other areas in California that receive shipments of East Coast baitworms, to determine if genes typical of *G. dibranchiata* from the U.S. East Coast, and more specifically genes typical of *G. dibranchiata* from Boothbay Harbor or other major baitworm-exporting areas, are present on the Pacific Coast.

**Table 6. Estimated numbers of organisms commonly imported and released with marine baitworms**

| | Mean number (or weight) per shipping box | Amount imported into Bay Area each year | Amount released into Bay or nearby coastal waters each year |
|---|---|---|---|
| Phaeophyta | | | |
| *Ascophyllum nodosum* | 1,166 grams | 9.3 metric tons | 2.8 metric tons |
| Annelida | | | |
| *Nereis virens* | 125 | 720,000 | ? |
| *Glycera dibranchiata* | 250 | 620,000 | ? |
| *Fabricia sabella* | 7 | 59,000 | 18,000 |
| Mollusca | | | |
| *Littorina littorea* | 5 | 37,000 | 11,000 |
| *Littorina obtusata* * | 24 | 193,000 | 58,000 |
| *Littorina saxatilis* | 6 | 45,000 | 13,000 |
| *Mytilus edulis* | 8 | 66,000 | 20,000 |
| Arthropoda | | | |
| Acarina (4 species) | 136 | 1,090,000 | 326,000 |
| Copepoda (3 species) * | 30 | 237,000 | 71,000 |
| *Jaera marina* | 45 | 362,000 | 109,000 |
| *Hyale nilssoni* * | 98 | 785,000 | 235,000 |
| All invertebrates other than baitworms and Nematoda | 484 | 3,870,000 | 1,160,000 |

* As noted above in Footnote 12, Lau (1995) collected a few organisms that had adhered to baitworms removed from the seaweed prior to sampling. If the numbers in this table are revised to account for these (Appendix 9), then the estimated numbers released into the Bay each year are about 74,000 each for the snail *Littorina obtusata* and copepods, 274,000 for the amphipod *Hyale nilssoni*, and just over 1.2 million for all invertebrates except nematodes.

## The Establishment of Non-indigenous Organisms

We have identified four Atlantic organisms that may have been temporarily or permanently established in San Francisco Bay as a result of the importing and sale of marine baitworms from Maine, which as discussed above apparently began around 1962-64.

*Littorina littorea* is a large periwinkle from the northeastern Atlantic that became established in the western Atlantic by the 19th century, where field experiments suggest that it has modified or reduced mudflat and saltmarsh habitat in protecetd coastal waters (Bertness 1984). It has been collected in San Francisco Bay several times since 1968 (Carlton 1969; unpublished data). During two periods in 1968-70 and 1976-77, several individuals of this species were collected over many months time, each time in a relatively small portion of the Bay (Table 7), suggesting that a population had become locally established. Neither of these populations appear to have persisted, however, and *L. littorea* does not appear to be presently established in San Francisco Bay. We found *L. littorea* to be very common in the *Ascophyllum nodosum* growing in the intertidal zone near Wiscasset, Maine; we observed many *L. littorea* being packed along with *Ascophyllum* into baitworm shipping boxes in Wiscasset; and we found *L. littorea* to be abundant in our qualitative and quantitative samples of baitworm shipments arriving in California.

**Table 7. *Littorina littorea* collected in San Francisco Bay**

| General location | Date | Site | Number of specimens | Collector |
|---|---|---|---|---|
| Berkeley shore | 06/11/68 | south Berkeley | 1 | Carlton |
| Oakland Estuary and | 12/12/68 | Alameda Island, SW? shore | 5 | Yancey |
| San Leandro Bay | 11/10/69 | Alameda Island, S shore | 1 | Yancey |
| | 11/23/69 | Bay Farm Island, NE shore | 6 | Yancey |
| | 08/17/70 | Alameda Island, SW shore | 1 | Carlton |
| San Pablo Bay, SE shore | 10/16/76 | Selby, near Union Oil | 1 | Pitt |
| | 04/16/77 | Selby, near Union Oil | 5 | Pitt |
| San Francisco shore | 05/14/95 | N of Hunters Point | 1 | Cohen |

*Littorina saxatilis* is a periwinkle native to the northeastern and northwestern Atlantic. Since 1993 we have found three established populations of this periwinkle in parts of San Francisco Bay (Carlton & Cohen 1998; unpublished data). *L. saxatilis* has non-planktonic larvae and is thus an unlikely candidate for transport in ships' ballast water, but we found it to be abundant in our qualitative and quantitative samples of Maine baitworm shipments arriving in California. Once released, its non-planktonic larvae may give it an advantage in becoming established, by reducing larval dispersal and increasing the probability that adults will settle in close enough proximity that they can later locate mates (Carlton & Cohen 1998). Each of the three populations in the Bay occurs over a very small area, which is what we would expect of a weakly-dispersing organism shortly after its establishment, and all three are immediately adjacent to either a public boat-launching ramp or small-boat docks, which are likely spots for the discarding of unused fishing bait. We believe that. *L. saxatilis* was almost certainly introduced via baitworm imports.[16]

*Carcinus maenas*, the European green crab, was introduced to the northwestern Atlantic by the early 19th century, where it has become very abundant and where its depredations are believed to have caused major reductions in commercial clam fisheries (Cohen *et al*. 1995). It subsequently became established and abundant in southern Australia by 1900 and was found in Tasmania in 1993, where there have also been concerns about its impact on shellfisheries, and has become established but not abundant in South Africa since 1983.[17] It was found in San Francisco Bay in 1989-90, where it is well-established, and has spread rapidly up the coast with recent records as far north as Vancouver Island in British Columbia (Carlton and Cohen 2001). In reviewing mechanisms that might have been responsible for its introduction to San Francisco Bay, we noted that if baitworm imports were responsible then genetic analysis should show that the immediate source was the northwestern Atlantic population (Cohen *et al*. 1995), which has subsequently been shown to be the case (Bagley and Geller 2001). *C. maenas* is very common in the intertidal *Ascophyllum nodosum* near Wiscasset, Maine, we recovered several (ranging from 9-39 mm in width) being packed along with *Ascophyllum* into baitworm shipping boxes in Wiscasset, and we have occasionally found them in our qualitative samples of baitworm shipments ariving in California. We believe that *C. maenas* was likely introduced via baitworm imports.

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16 As discussed by Carlton and Cohen (1998), genetic differences have been found between *L. saxatilis* populations in the Atlantic, and genetic analysis of San Francisco Bay populations could probably determine whether they were introduced via baitworms or by other mechanisms.

17 The South African population includes some genes of a sibling species from the Mediterranean, *Carcinus aestuarii* , but has the appearance of *C. maenas*. A Japanese population, established by 1984, has the appearance of *C. aestuarii* but includes some genes of *C. maenas* (Geller *et al*. 1997).

*Codium fragile tomentosoides*, a green seaweed variously called dead-man's fingers, oyster thief and Sputnik weed, is native to Japan. It became established in Europe in the 19th century, and spread across the Atlantic and reached Boothbay Harbor, Maine by 1964 (Coffin and Stickney 1967; Carlton and Scanlon 1985). It was first collected inthe northeastern Pacific Coast in San Francisco Bay in 1973 (P. Silva, pers. comm. 1997). Dawson and Foster (1982) reported that it was introduced as discards from its use as "packing material to ship live marine bait worms from New England to San Francisco Bay," but we have been unable to trace the evidence for that claim (M. Foster, pers. comm. 1997; P. Silva, pers. comm. 1997; R. Moe, pers. comm. 1997). From our observations, interviews and the published literature we found no indication that *Codium* is now or ever was used as packing material for shipments of Maine baitworms, though we cannot entirely rule it out. Nor did we observe any *Codium* being incidentally packed with *Ascophyllum* for baitworm shipments from Maine, or find it in any of our qualitative or quantitative samples of baitworm shipments in California. However, *Codium* has been found among or attached to *Ascophyllum nodosum* in New England (Coffin and Stickney 1967; Carlton and Scanlon 1985). This, plus the discovery of *C. f. tomentosoides* in San Francisco Bay within a decade of its arrival in Boothbay Harbor and the initiation of baitworm shipments to the San Francisco Bay area, lead us to conclude that *C. f. tomentosoides* may have been introduced to the northeastern Pacific via the baitworm trade. As with *Carcinus maenas*, we suggest that genetic analysis of northeastern Pacific populations and possible source populations may shed light on this question, particularly if the Boothbay Harbor population, which was isolated from other Atlantic populations for at least 20 years, can be genetically distinguished from them.[18]

Global Implications

The primary market for Maine's pileworms and bloodworms is in the other Northeastern and Middle Atlantic U.S. states, particularly in the region from Long Island Sound to Chesapeake Bay (Pettibone 1963; Dow and Creaser 1970), with shipments reported as far south as South Carolina, Florida and the Gulf Coast (Creaser *et al*. 1983; Olive 1994). These worms are also regularly shipped from Maine (and sometimes from Atlantic Canada) to various countries in Europe, including Italy, France and Spain (Creaser *et al*. 1983; Brown 1993; P. Fairservice, pers. comm. 1994; F. Hammond, pers. comm. 1996; S. Fairservice, pers. comm. 1996), and less commonly to Korea, Japan and South America (Olive 1994; B. Brown, pers. comm. 1996; E. Creaser, pers. comm. 1996). Our interviews indicate that the baitworms shipped out from Maine would in all cases be packed in *Ascophyllum nodosum*, just as they are for the California market, carrying a presumably similar suite of living New England intertidal organisms to these distant corners of the globe.

Table 8 lists a few of the international shipping routes for marine baitworms, though there are undoubtedly others. As trade barriers are further broken down and new overseas markets are opened up, we can expect yet additional species of marine worms to be shipped around the globe, along with packing materials and attendant other organisms, to supply the needs of the world's anglers. For example, in the mid-1990s a subtropical marine worm imported from Southeast Asia, *Namalycastis abiuma*, began appearing in a few baitshops on both coasts of the U.S.[19] One study found that two serotypes of *Vibrio cholerae*, the bacterium that causes cholera, had been carried

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[18] This seems likely to be the case, since Malinowski (1974) found both physiological differences and some evidence of genetic differences between the Boothbay Harbor population and populations in Connecticut, New York and New Jersey.

[19] Five of the shops that we interviewed in the San Francisco Bay Area stated that they carried or had carried this worm, which was marketed on the West Coast under the name "Magic Cord." On the east Coast it was marketed as the "Nuclear Worm," apparently a reference to its explosive potency as fishing bait, but perhaps thought to be enviro-politically unacceptable in California.

with these worms from Vietnam to Maryland and Virginia (Mullady *et al*. 2000).[20] As to which other organisms are incidentally transported around the world with the global trade in marine baitworms, little is known.

**Table 8. Examples of international and interoceanic shipments of marine baitworms**

| Baitworm | Sources | Markets | References |
|---|---|---|---|
| *Glycera dibranchiata* | Atlantic N. America | Pacific USA, Italy | Gambi *et al*. 1994; this paper |
| *Nereis virens* | Atlantic N. America | Pacific USA, Italy, France | Gambi *et al*. 1994; Olive 1994; this paper |
| | UK, Spain | Italy | Gambi *et al*. 1994 |
| | Ireland, Netherlands | UK, France, Spain, Italy | Olive 1994 |
| *Glycera dibranchiata* and/or *Nereis virens* | Atlantic USA | South America, Korea, Japan, France, Spain, Italy | Olive 1994; P. Fairservice, pers. comm. 1994; E. Creaser, B. Brown & S. Fairservice, pers. comm. 1996 |
| *Perinereis aibuhitensis* | SE Asia | Italy | Gambi *et al*. 1994 |
| *Perinereis brevicirrus* | Korea | Japan, USA, Europe | Olive 1994 |
| | Taiwan | Japan | Olive 1994 |
| *Perinereis cultifera* | France | Italy | Gambi *et al*. 1994 |
| *Perinereis nuntia* | China | Japan | Olive 1994 |
| *Perinereis nuntia vallata* | Japan | Italy | Gambi *et al*. 1994 |
| *Perinereis vancauria* | Korea | Italy | Gambi *et al*. 1994 |
| *Perinereis* spp. | Korea | Japan, France | Olive 1994 |
| *Hediste versicolor* | France | Italy | Gambi *et al*. 1994 |
| *Marphysa sanguinea* | USA | Italy | Gambi *et al*. 1994 |
| | Korea | Japan, USA, France, Italy | Gambi *et al*. 1994; Olive 1994 |
| | Italy | southern Europe | Olive 1994 |
| *Arenicola marina* | Ireland, UK, France, Netherlands | Europe | Olive 1994 |
| *Namalycastis abiuma* | Vietnam | Atlantic USA | Mullady *et al*. 2000 |
| | SE Asia | Japan, Korea, Australia, Europe, Pacific USA | Universal Bait Co. sales letter, 1995; this paper |

[20] *Vibrio* species apparently adhere to the chitinized body parts of marine invertebrates, such as the jaws of some marine worms. A related bacterium, *Vibrio parahaemolyticus*, is associated with Tentacle Wasting disease in pileworms reared in culture in England (Olive 1994)

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We wish to thank the bait dealers and baitshop owners in Maine and California who patiently agreed to be interviewed and who allowed us to search for organisms among their baitworms and packing seaweed. Although many of them recognized that this research might someday lead to regulations affecting the baitworm trade and its use of seaweed packing, they were nevertheless quite willing to assist us, either because of their interest in the phenomenon we were investigating, their concerns about the introduction of non-indigenous organisms, or their easy-going friendliness. Stanley and Patty Fairservice and Bob Nakaji were especially helpful to us.

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**Appendix 1. Wholesale distributors of marine baitworms in the San Francisco Bay Area**

| Distributor | City | Telephone |
|---|---|---|
| Colombo Bait, Inc. | San Rafael | 415-459-2811 |
| Cove Wholesale Bait & Tackle | – | 707-263-3113 |
| Hillcrest Farms Bait | Watsonville | 408-722-9177 |
| I.H.O. Distributing | West Sacramento | 916-373-1888 |
| Loch Lomond Bait | San Rafael | – |
| Pacific Bait | Elk Grove | – |

**Appendix 2. Survey questions**

**Baitworm Survey**
**San Francisco Estuary Institute**

**Date:** _____ **Time:** _____ **Interviewer:** _____

**Bait Shop/Distributor:** _____ **Phone:** _____

**Address:** _____

**Introduction:** Hello, my name is _____. I'm with the San Francisco Estuary Institute. We are trying to gather some information on the inmportation of baitworms into the Bay Area because there is a concern that the seaweed packing may be a source of introductions of exotic species into the Bay. Would you be willing to answer a few questions about the baitworms that you carry?

1. Do you sell bloodworms or pileworms (also known as clamworms or sandworms)? Do you sell Asian worms (known as "Magic Cord")?
2. Where do you get your baitworms?
3. How many (packing boxes) do you sell per year?
4. When did you start carrying (importing) them? How long have you been selling them?
5. Have the number of baitworms that you sell each year been increasing or decreasing?
6. Is there a particular time of the year that you sell (import) them?
7. What do you do with the seaweed packing?
8. How do you provide your customers with the baitworms (with or without seaweed)?
9. Would you be willing to provide us with samples of your leftover seaweed packing?

**Appendix 3. Yellow pages used to compile the list of greater San Francisco Bay Area bait shops**

| | |
|---|---|
| Contra Costa - Central | Palo Alto / Redwood City / Menlo Park |
| Contra Costa - East | Sacramento |
| Contra Costa - West | San Francisco |
| Fairfield / Vacaville / Suisun City / Dixon | San Jose / Santa Clara |
| Fremont / Hayward / Castro Valley / Newark / Union City | San Mateo - Central |
| Lake / Mendocino Counties | San Mateo - North |
| Lodi / Galt | Sonoma County |
| Los Altos / Los Altos Hills / Mountain View / Sunnyvale | Tracy |
| Marin County | Tri-Valley |
| Napa Valley | Vallejo / Benicia |
| Oakland / Berkeley | |

**Appendix 4. Bait shops in the greater San Francisco Bay Area**

| Bait shop | Address | City | Telephone |
|---|---|---|---|
| A & M Market [c] | 2877 Solano Ave. | Napa | 707-255-0400 |
| A-1 Arco Bait Shop [c] | 889 Grand Ave. | Oakland | 510-465-4450 |
| Alviso Boat Dock [c] | 1160 Taylor | Alviso | 408-262-3885 |
| Angler's Choice Bait & Tackle [d] | 219 E. Kettleman Ln. | Lodi | 209-368-6973 |
| Armanino's [c] | 329 Grand Ave. | S. San Francisco | 415-588-0245 |
| Bales Bait & Tackle [c] | Highway 160 | Antioch | 510-757-3852 |
| Berkeley Marina Bait & Tackle [c] | 225 University Ave. | Berkeley | 510-849-2727 |
| Big T Liquor & Bait [c] | 16344 San Pablo Ave | San Pablo | 510-724-5485 |
| Blue Star Gas & Mart [d] | 1541 East Cypress Rd. | Oakley | 510-625-3900 |
| Bodega Bay Sport Fishing Center [c] | 1500 Bay Flat Rd. | Bodega Bay | 707-875-3344 |
| Bottom's up Liquor & Market [c] | 1366 Fitzuren Rd. | Antioch | 510-778-3061 |
| Broadway Bait, Rod & Gun [c] | 1701 Broadway | Sacramento | 916-448-6338 |
| Burn's Wurm Furm [d] | 239 4th St. | Galt | 209-745-2288 |
| California Parks Company [c] | Lake Del Valle | Livermore | 510-449-5201 |
| California Parks Company [c] | Shadow Cliffs Reservior | Pleasanton | 510-846-9263 |
| California Parks Company [c] | Lake Chabot | Castro Valley | 510-582-2198 |
| California Parks Company [c] | Lake Merced | San Francisco | 415-753-1101 |
| California Parks Company [c] | Lake Camanche | Ione | 209-763-5121 |
| California Parks Company [c] | 7301 San Pablo Dam Rd. | El Sobrante | 510-223-1661 |
| Camanche Recreation Co. - North | 2000 Camanche Rd. | Ione | 209-763-5121 |
| Camanche Recreation Co. - South | 5908 Pattison Rd. | Wallace | 209-763-5178 |
| Caruso's Sportfishing Center [c] | Foot of Harbor Drive | Sausalito | 415-332-1015 |
| Captain John's | 111 Pillar Point Harbor | Half Moon Bay | 415-726-2913 |
| Castro Valley Sportsman's Center [c] | 3794 Castro Valley Blvd. | Castro Valley | 510-537-8191 |
| Central Avenue Bait & Tackle Shop [c] | 641 Central Ave. | Alameda | 510-522-6731 |
| Chuck's Bait & Tackle [c] | 3995 Willow Rd. | Bethel Island | 510-684-0668 |
| Coastside No. 2 Bait & Tackle [c] | 1604 Francisco Blvd. | Pacifica | 650-359-9790 |

| | | | |
|---|---|---|---|
| Colombo Bait, Inc. [c w] | 1495 Francisco Blvd. | San Rafael | 415-459-2811 |
| Colombo's Liquors [c] | 507 Linden Ave. | S. San Francisco | 415-583-0236 |
| Cove Wholesale Bait & Tackle [c w] | – | – | 707-263-3113 |
| Coyote Discount Bait & Tackle [c] | 8215 Monterey Rd. | Coyote | 408-463-0711 |
| Delta Bait & Tackle [c] | 2201 E. Yosemite Ave. | Manteca | 209-239-2248 |
| Delta Sportsman Inc. [c] | 6131 Bethel Island Rd. | Bethel Island | 510-684-2260 |
| Diego's of Port View Park [c] | 4003 7th St. | Oakland | 510-452-8992 |
| Don's Bait Shop [c] | 14465 Lakeshore Dr. | Clearlake | 707-995-9668 |
| Dry Creek General Store [c] | 3495 Dry Creek Rd. | Healdsburg | 707-433-4171 |
| Ed's Bait & Tackle [c d] | 867 Gravenstien Highway S. | Sebastopol | 707-823-2277 |
| Elkhorn Bait & Tackle [c] | 6745 20th St. | Rio Linda | 916-991-5298 |
| Fish and Dive Shop | 3590 Peralta Blvd. | Fremont | 510-794-3474 |
| Fisherman's Cove Resort [c] | 2435 Lakeshore Blvd. | Nice | 707-274-1301 |
| Fisherman's Friend [c] | 440 Kettleman Ln. | Lodi | 209-369-0204 |
| Fishery Supply [c w] | 972 Story Rd. | San Jose | 408-293-6593 |
| Frank's Bait & Tackle [c] | 600 Railroad Ave. | Pittsburg | 510-473-0620 |
| Freeport Bait [c] | 8250 Freeport Blvd. | Sacramento | 916-665-1935 |
| Fruitridge Bait & Tackle Shop [c] | 4131 Fruitridge Rd. | Sacramento | 916-456-7506 |
| Glenhaven Beach Campgrnd + Marina | 9625 E. Highway 20 | Glenhaven | 707-998-3406 |
| Gotcha Bait & Tackle | 3500 E. 18th St. | Antioch | 510-706-7400 |
| Grand Harbor Fuel Dock | 2099 Grand Ave. | Alameda | 510-521-3835 |
| Grand Street Bait & Tackle [c] | 1926 Grand St. | Alameda | 510-521-2460 |
| Happy Hooker Worm Farm & Bait | 6805 Vaughn Rd. | Dixon | 916-678-4980 |
| Harris Yacht Harbor Bait Shop [c] | 100 Trojan Rd. | Pittsburg | 510-458-4904 |
| Hook Line & Sinker [c] | 98 Big Break Blvd. | Oakley | 510-625-2441 |
| Hook Line & Sinker [d] | 2114 El Camino Ave | Sacramento | 916-567-9574 |
| Huck Finn Sportfishing [c] | Pillar Point Harbor | El Granada | 415-726-7133 |
| J & P Bait Co. [c] | 54 Holstrom Circle | Novato | 415-893-0321 |
| Johnson's Bait [c] | 111 Cutting Blvd. | Bethel Island | 510-235-5335 |
| Ken's Bait & Tackle [c] | 2677 Union Ave. | San Jose | 408-371-0370 |
| King's Bait & Tackle [c] | 51 Marina Blvd. | Pittsburg | 510-432-8466 |
| King's Sport & Tackle [c] | 16258 Main St. | Guerneville | 707-869-2156 |
| Laine's Bait Shop [c] | 970 Elizabeth | Alviso | 408-262-0349 |
| Lake Chabot Fishing Outfitters [c] | 17936 Lake Chabot Rd. | Castro Valley | 510-582-2198 |
| Lake Merced Boating & Fishing Co. [c] | 1 Harding Rd. | San Francisco | 415-753-1101 |
| Limit Out Bait & Tackle [c] | 12599 E. Highway 20 | Clearlake Oaks | 707-998-1006 |
| Loch Lomond Live Bait House [c] | Dock A, Loch Lomond Harbor | San Rafael | 415-456-0321 |
| Lucky Bait Shop [c] | 2617 San Pablo Ave. | Berkeley | 510-704-8990 |
| McAvoy Bait [c] | 1001 Mc Avoy Rd. | Pittsburg | 510-458-1710 |
| Marina Concessions [c] | 260 Sears Point Rd. | Petaluma | 707-762-7818 |
| Marina Liquors [c] | 2260 Marina Blvd. | San Leandro | 510-483-4030 |
| Maritme Market & Bait Shop [c] | 3098 Polk St. | San Francisco | 415-9291655 |
| Martinez Marina Bait & Tackle [c] | 95 Tarantino Dr. | Martinez | 510-229-9420 |

| | | | |
|---|---|---|---|
| Millie's J&M Bait Shop & Market [c] | 900 Sonoma Blvd. | Vallejo | 707-642-6920 |
| Monterey Bait & Tackle Shop [c] | 4715 International Blvd. | Oakland | 510-261-5562 |
| Mountain View Ice Co. [c] | 404 Villa | Mountain View | 415-967-7792 |
| Munoz Liquors & Groceries [c] | 37695 Niles Blvd. | Fremont | 510-797-7151 |
| New Hope Landing & Trailer Park [c] | 13945 W. Walnut Grove Rd. | Thornton | 209-794-2627 |
| Norm's Bait & Tackle [c] | 3 Curtola Pkwy. | Vallejo | 707-642-4330 |
| Outdoor Pro Shop [c] | 6315 Commerce Blvd. | Rohnert Park | 707-588-8033 |
| PAC Bait & Tackle Co. | 6334 San Pablo Ave. | Oakland | 510-652-7102 |
| Penny Rod & Bait [c] | 1271 Merkley Ave. | Waits Station | 916-372-8813 |
| Perry's Bait & Tackle Shoppe [c] | 312 Curtola Pkwy | Vallejo | 707-552-5319 |
| Petaluma Sport Shop & Dive [c] | 884 Bodega Ave. | Petaluma | 707-763-0930 |
| Pierce Harbor Bait & Tackle [d] | 14 Pierce Harbor Lane | Suisun | 707-864-8923 |
| Puddle Jumper Bait & Tackle | 36768 Cedar Blvd. | Newark | 510-790-3472 |
| Rodeo Sports & Liquors [c] | 133 Parker Ave. | Rodeo | 510-799-2816 |
| Roger's Bait & Tackle | 3315 Northgate Blvd. | Sacramento | 916-922-5781 |
| Sacramento Pro Tackle [c] | 2390 Northgate Blvd. | Sacramento | 916-925-0529 |
| Scotty's Bait & Tackle [c] [d] | 574 W Grant Line Rd. | Tracy | 209-835-3415 |
| Sherwood Harbor Marina [c] | 3505 South River Rd. | Waits Station | 916-371-3471 |
| Solano Marine Bait & Tackle [d] | 310 Spring | Suisun | 707-421-2248 |
| Store 24 - Kelseyville [c] | 5475 Main St. | Kelseyville | 707-279-1791 |
| Sun Valley Bait & Tackle [c] | 620 S. Norfolk | San Mateo | 650-343-4690 |
| Tackle Shop [c] | 509 Claverie Way | Benicia | 707-745-4921 |
| Tides Warf Fish Market [c] | Highway 1 | Bodega Bay | 707-875-3554 |
| TNT Liquor & Bait [c] | 27575 Misson Blvd. | Bethel Island | 510-537-1600 |
| Tony's Sporting Goods [c] | 3841 First St. | Livermore | 510-443-9191 |
| Universal Bait | 972 Story Rd. | San Jose | 408-292-2248 |
| Valley Bait & Tackle [c] | 126 W. Turner Rd. | Lodi | 209-367-4516 |
| Virgil's Bait Shop & Ice House [c] | 201 Main St. | Suisun | 707-425-5518 |
| Walton's Pond [c] | 14837 Washington Ave | San Leandro | 510-352-3932 |
| Western Boat & Tackle [c] | 101 3rd St. | San Rafael | 415-454-4177 |
| Western Sport Shop [c] | 902 3rd. St. | San Rafael | 415-456-5454 |
| Wiggle Worm Baits | P.O. Box 14156 | Sonoma | 707-527-8429 |
| Wong's Bait & Tackle [d] | 1630 Post St. | San Francisco | 415-563-9819 |

[c] Contacted.

[w] Bait wholesaler (distributor).

[d] Telephone number was disconnected, with no new number given.

**Appendix 5. Qualitative samples collected in 1995-1998**

| Date | Quantity examined | Baitshop | Collected by |
|---|---|---|---|
| <03/31/95 | 1 box? | #5 | ANC |
| 04/28/95 | 7 boxes | #5 | ANC |
| 10/02/96 | 1 old box | #6 | ANC/JTC |
| 05/06/97 | 1 box | #7 | ANC |
| 12/08/97 | 1 box | #13 | MAE |
| 12/09/97 | 1 box | #1 | MAE |
| 12/17/97 | 1 box | #1 | MAE |
| 08/25/98 | 1 box | #1 | AW |
| 09/22/98 | 1 box | #4 | AW |
| 09/28/98 | 1 box | #2 | AW |
| 10/06/98 | 2 new boxes | #8 | AW |
| 10/10/98 | ? | #1 | AW |

**Appendix 6. Quantitative samples collected in 1998**

| Date | Bait shop | Box | Worms | Condition of box | Hours since delivery | Number of subsamples |
|---|---|---|---|---|---|---|
| 08/25/98 | #1 | #1 | pileworms | intact | 3 | 2 |
| 09/24/98 | #3 | #1 | pileworms | intact | 4 | 1 |
| 09/24/98 | #9 | #1 | pileworms | seaweed removed | 48 | 1 |
| 09/24/98 | #9 | #2 | pileworms | seaweed removed | 48 | 1 |
| 09/28/98 | #4 | #1 | bloodworms | intact | 24 | 1 |
| 09/28/98 | #4 | #2 | pileworms | intact | 24 | 1 |
| 10/05/98 | #4 | #1 | bloodworms | intact | 2 | 2 |
| 10/05/98 | #8 | #1 | bloodworms | worms & seaweed removed | 48 | 2 |
| 10/06/98 | #8 | #1 | pileworms | intact | 3 | 6 |
| 10/06/98 | #8 | #2 | bloodworms | worms & seaweed removed | 3 | 4 |
| 10/12/98 | #13 | #1 | bloodworms | intact | 24 | 4 |
| 10/12/98 | #1 | #1 | pileworms | worms & seaweed removed | 24 | 4 |
| 10/28/98 | #13 | #1 | bloodworms | worms & seaweed removed | 24 | 11 |
| 10/28/98 | #10 | #1 | bloodworms | worms & seaweed removed | 48 | 4 |
| 11/10/98 | #1 | #1 | pileworms | worms & seaweed removed | 48 | 8 |
| 11/10/98 | #1 | #2 | bloodworms | worms & seaweed removed | 48 | 5 |
| Total: | 7 shops | 16 boxes | | | | 57 |

**Appendix 7. Organisms identified in marine baitworm shipments arriving in California**

| | 1970 samples (Carlton 1979) | 1994-95 quantitativesamples (Lau 1995)* | 1995-98 qualitative samples (this study) | 1998 quantitative samples (this study) |
|---|---|---|---|---|
| Fungi | | | | |
| *Pleospora* sp. | X | | | |
| Chlorophyta (epiphytic on *L. saxatilis*) | | | X | |
| Phaeophyta (epiphytic) | | X | | |
| *Fucus* sp. | | | X | |
| *Elachistea fucicola* | | X | | |
| Chrysophyta: Bacillariophyceae (chain) | | | X | |
| Plantae | | | | |
| *Zostera* sp. (fragments) | | X | | |
| *Spartina* sp. (fragments) | | | X | |
| Foraminifera | | | | X |
| *Trochammina inflata* | | X | | |
| Platyhelminthes | | | | X |
| Nematoda | | X | X | X |
| Annelida: Oligochaeta | | | | |
| Enchytraeidae sp. A | | X | | X |
| Annelida: Polychaeta | | | | |
| Capitellidae | | X | | X |
| *Fabricia sabella* | | X | | X |
| Mollusca (ctenidium) | | | | X |
| Mollusca: Gastropoda | | | | |
| *Lacuna vincta* | | X | | |
| *Littorina littorea* | X | X | X | X |
| *Littorina obtusata* | X | X | X | X |
| *Littorina saxatilis* | X | X | X | X |
| *Littorina* sp. (eggs) | | | X | |
| ?Hydrobiidae | | | X | X |
| Mollusca: Bivalvia | | | | |
| Mussel (nepionic) | | | | X |
| *Modiolus modiolus* | | | X | |
| *Mytilus edulis* | X | X | | X |
| Clam (nepionic) | | X | X | X |
| *Mya arenaria* (shell fragments) | | | X | |

**Appendix 7 (continued). Organisms identified in marine baitworm shipments arriving in California**

| | 1970 samples (Carlton 1979) | 1994-95 quantitativesamples (Lau 1995)* | 1995-98 qualitative samples (this study) | 1998 quantitative samples (this study) |
|---|---|---|---|---|
| Arthropoda: Chelicerata | | | | |
| Acarina sp. A (?Cryptostigmatidae) | | X | | X |
| Acarina sp. B | | | | X |
| ?*Halacarus* sp. A | | X | | X |
| ?*Halacarus* sp. B | | | X | |
| Arthropoda: Insecta | | | | |
| Diptera (larva) | | X | | X |
| ?Diptera (adult abdomen) | | | | X |
| Chironomidae (larva) | | | | X |
| Coleoptera | | | X | |
| Arthropoda: Ostracoda | | | | X |
| Arthropoda: Copepoda | | | | |
| Harpacticoida sp. A | | X | | X |
| Harpacticoida sp. B | | X | | X |
| Harpacticoida sp. C | | X | | X |
| ?Cyclopoida | | X | | |
| Arthropoda: Isopoda | X | | | |
| *Jaera marina* | | X | X | X |
| Arthropoda: Tanaidacea | | | X | |
| Arthropoda: Amphipoda | | | | |
| Gammaridea | X | X | X | |
| *Hyale nilssoni* | | X | X | X |
| Arthropoda: Decapoda | | | | |
| *Carcinus maenas* | | | X | |

* Includes re-examination of Lau's samples in 1999 to confirm and augment Lau's identifications, including some samples collected by Lau but not reported in Lau (1995).

**Appendix 8. Numbers of organisms collected in quantitative samples**

| Date: | 10/12/94 | 10/12/94 | 01/28/95 | 10/17/94 | 10/17/94 | 03/??/95 | 08/25/98 | 08/25/98 | 09/24/98 | 09/24/98 | 09/24/98 | 09/28/98 | 09/28/98 | 10/05/98 | 10/05/98 | 10/05/98 | 10/05/98 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baitshop: | 11 | 11 | 11 | 12 | 12 | 1 | 1 | 1 | 3 | 9 | 9 | 4 | 4 | 4 | 4 | 8 | 8 |
| Platyhelminthes | | | | | | | | | | | | | | | | | |
| Enchytraeidae | 2 | 1 | | | | | | | | | | | | | | | |
| Capitellidae | | | | | | 1 | | | | | | | | | | | |
| *Fabricia sabella* | | | | 4 | | | | | | | | | | | | | |
| *Lacuna vincta* | 1 | | | | | | | | | | | | | | | | |
| *Littorina littorea* | 1 | | | | | | 1 | | | | | | | | | | |
| *Littorina obtusata* | 1 | 6 | 1 | 1 | | | | | | | | | | | | | |
| *Littorina saxatilis* | 2 | 2 | 1 | | | | | | | | | | | | | | |
| ?Hydrobiidae | | | | | | | | | | | | | | 2 | | 1 | |
| *Mytilus edulis* | 1 | | | 3 | 3 | | | | | | | | | | | | |
| nepionic mussel | | | | | | | 3 | | | | | | 1 | 1 | | | |
| nepionic clam | | | | | | | | | | | | | 2 | | | | |
| Insecta | | 2 | | | | | 1 | | | | | | 2 | | | 2 | |
| Acarina | 5 | 3 | 4 | 5 | | 21 | | | | 1 | | | 13 | | | | |
| Copepoda | | 1 | | 8 | 2 | 2 | | | | | | | | | | | |
| Ostracoda | | | | | | | | | | | | | | | 2 | | |
| *Jaera marina* | 14 | 9 | 3 | 2 | 1 | | | | | | | 1 | | | | 1 | |
| *Hyale nilssoni* | 2 | 2 | | 1 | | | 3 | | | 1 | 3 | 4 | | 1 | 3 | 1 | 5 |
| Gammaridea | 1 | | | | | | | | | | | | | | | | |
| Number of invertebrates, excluding Nematoda | 30 | 26 | 9 | 24 | 6 | 24 | 8 | 0 | 0 | 2 | 3 | 5 | 18 | 4 | 5 | 5 | 5 |

**Appendix 8 (continued). Numbers of organisms collected in quantitative samples**

| Date: | 10/06/98 | 10/06/98 | 10/06/98 | 10/06/98 | 10/06/98 | 10/06/98 | 10/06/98 | 10/06/98 | 10/06/98 | 10/06/98 | 10/12/98 | 10/12/98 | 10/12/98 | 10/12/98 | 10/12/98 | 10/12/98 | 10/12/98 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baitshop: | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 13 | 13 | 13 | 13 | 1 | 1 | 1 |
| Platyhelminthes | | | | | | | | | | | | | | | | | |
| Enchytraeidae | | 1 | | | 1 | | | 1 | | | | | | 1 | 1 | | |
| Capitellidae | | | | | | | | | | | | | | | | | |
| *Fabricia sabella* | | | | | | | | | | | | | | | 3 | | |
| *Lacuna vincta* | | | | | | | | | | | | | | | | | |
| *Littorina littorea* | | | | | | | | | | | | | | | | | |
| *Littorina obtusata* | | | | | | | | | | | | | | | | | 3 |
| *Littorina saxatilis* | | | | | | | | | | | | | | | | | |
| ?Hydrobiidae | | | | | | | | 1 | | | | | | | | | |
| *Mytilus edulis* | | | | | | | | | | | | | | | | | |
| nepionic mussel | 1 | 5 | | | | 1 | | | 1 | | | | 1 | 1 | | | |
| nepionic clam | | | | 1 | | | | | | | | 1 | | 1 | | | |
| Insecta | | | | | | | | | | | | | | | | | |
| Acarina | | 7 | 3 | 2 | | | | | | | 3 | 10 | 6 | 9 | 3 | 1 | 2 |
| Copepoda | | 1 | 1 | | 3 | | 1 | | | | 1 | 3 | | 1 | | | |
| Ostracoda | | | | | | | | | | | | | | | | | 6 |
| *Jaera marina* | | 1 | | | 1 | | 2 | | | | | 1 | | | | 1 | 1 |
| *Hyale nilssoni* | 1 | 1 | 2 | 1 | 1 | | | | 6 | 2 | | | 1 | | 3 | 9 | |
| Gammaridea | | | | | | | | | | | | | | | | | |
| Number of invertebrates, excluding Nematoda | 2 | 16 | 6 | 4 | 6 | 1 | 3 | 2 | 7 | 2 | 4 | 15 | 8 | 13 | 10 | 11 | 12 |

**Appendix 8 (continued). Numbers of organisms collected in quantitative samples**

| Date: | 10/12/98 | 10/28/98 | 10/28/98 | 10/28/98 | 10/28/98 | 10/28/98 | 10/28/98 | 10/28/98 | 10/28/98 | 10/28/98 | 10/28/98 | 10/28/98 | 10/28/98 | 10/28/98 | 10/28/98 | 10/28/98 | 11/10/98 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baitshop: | 1 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 10 | 10 | 10 | 10 | 1 |
| Platyhelminthes | | | | | | | | 1 | | | | | | | | | |
| Enchytraeidae | | | | | 2 | 2 | 1 | | 2 | | | | 18 | | | 1 | |
| Capitellidae | | | | | | | | | | | | | | | | | 2 |
| *Fabricia sabella* | | | | | | | | | | | | | | | | 1 | |
| *Lacuna vincta* | | | | | | | | | | | | | | | | | |
| *Littorina littorea* | | | | 2 | | | | | | | | | | | | | |
| *Littorina obtusata* | 4 | | 1 | 1 | | | | | | | | | | 4 | 1 | 3 | |
| *Littorina saxatilis* | | | | | | | | | | | | | | | | 1 | |
| ?Hydrobiidae | | | | | | | | | 2 | | | | | | | | |
| *Mytilus edulis* | | | | | | | | | | | | | | | | | 1 |
| nepionic mussel | | 2 | | | | | | 2 | 1 | | | 1 | 3 | 2 | | | 1 |
| nepionic clam | | | | | | | | | | | | | 3 | | | | |
| Insecta | | | | | | | | | | | | | | | | | |
| Acarina | 1 | | | | 2 | 1 | 1 | 1 | 3 | 4 | 4 | | 10 | | | 2 | 6 |
| Copepoda | | | | | | | | | | | | | 3 | | | | 1 |
| Ostracoda | 3 | 1 | | | 1 | | 1 | | 3 | | 2 | | | | | | |
| *Jaera marina* | | | 2 | | 1 | 1 | 1 | 1 | 1 | | | | | | | | 1 |
| *Hyale nilssoni* | 1 | | | | 1 | | 4 | 1 | | | 15 | 4 | 2 | 1 | | 1 | 1 |
| Gammaridea | | | | | | | | | | | | | | | | | |
| Number of invertebrates, excluding Nematoda | 9 | 3 | 3 | 3 | 7 | 4 | 8 | 6 | 12 | 4 | 21 | 5 | 39 | 7 | 1 | 9 | 13 |

**Appendix 8 (continued). Numbers of organisms collected in quantitative samples**

| Date: | 11/10/98 | 11/10/98 | 11/10/98 | 11/10/98 | 11/10/98 | 11/10/98 | 11/10/98 | 11/10/98 | 11/10/98 | 11/10/98 | 11/10/98 | 11/10/98 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Baitshop: | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Platyhelminthes | | | | | | | | | | | | |
| Enchytraeidae | | | | | | | | | | | | |
| Capitellidae | | | | | | 2 | | | | | | |
| *Fabricia sabella* | | | | | | | | | | | | |
| *Lacuna vincta* | | | | | | | | | | | | |
| *Littorina littorea* | | | | 1 | | | | | | | | |
| *Littorina obtusata* | | | | | | | | | | | | |
| *Littorina saxatilis* | | | | | | | | | | | | |
| ?Hydrobiidae | | | | | | | | | | | | 1 |
| *Mytilus edulis* | | | | | | 1 | | | | | | |
| nepionic mussel | 1 | 1 | | | 3 | 5 | 1 | 1 | | | | 2 |
| nepionic clam | | | | | | | | | | | | |
| Insecta | | | | | | | | | | | | |
| Acarina | | 2 | 1 | 4 | 1 | 3 | 1 | | | 2 | | |
| Copepoda | | | | 3 | | | | | | 1 | | |
| Ostracoda | | | | 1 | | 2 | | 1 | 1 | 2 | 4 | |
| *Jaera marina* | 1 | | | | 1 | | | 1 | | | | |
| *Hyale nilssoni* | | | | 6 | 2 | 6 | | | | 2 | 3 | 3 |
| Gammaridea | | | | | | | | | | | | |
| Number of invertebrates, excluding Nematoda | 2 | 3 | 1 | 15 | 7 | 19 | 2 | 3 | 1 | 7 | 7 | 6 |

**Appendix 9. Mean numbers of some common organisms collected in quantitative samples**

| | Not including organisms collected on baitworms | | Adjusted for organisms collected on baitworms* | |
|---|---|---|---|---|
| | Mean number per sample | Mean number per shipping box | Mean number per sample | Mean number per shipping box |
| *Fabricia sabella* | .127 | 7.4 | .127 | 7.4 |
| *Littorina littorea* | .079 | 4.6 | .079 | 4.6 |
| *Littorina obtusata* | .413 | 24.1 | .527 | 30.7 |
| *Littorina saxatilis* | .095 | 5.6 | .095 | 5.6 |
| *Mytilus edulis* | .143 | 8.3 | .143 | 8.3 |
| Acarina | 2.33 | 136 | 2.33 | 136 |
| Copepoda | .508 | 29.6 | .527 | 30.7 |
| *Jaera marina* | .778 | 45.3 | .778 | 45.3 |
| *Hyale nilssoni* | 1.68 | 98.1 | 1.96 | 114 |
| Number of invertebrates, excluding Nematoda | 8.30 | 484 | 8.72 | 508 |

* Numbers for *Littorina obtusata*, Copepoda and *Hyale nilssoni* adjusted upward in proportion to the numbers collected by Lau (1995) on the baitworms removed from her seaweed samples.