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Experiments in the Control of Shipworm *Toredo* Sp. Using Bis (Tri-N-Butyltin) Oxide

by M.L.H. Thomas

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TECHNICAL REPORT NO. 21

ERRATUM

Please note that the cover title for Technical Report No. 21 (1967) should have read:

Experiments in the Control of Shipworm Teredo Sp. Using Bis(Tri-N-Butyltin) Oxide.

EXPERIMENTS IN THE CONTROL OF SHIPWORM TEREDO SP. USING BIS(TRI-N-BUTYLTIN) OXIDE*.

*(bioMet TBTO. M and T Chemicals Inc., Rahway, N.J., U.S.A.)

by

M. L. H. Thomas

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Introduction

Shipworms of the genus *Teredo* (Mollusca - Pelecypoda) are present throughout the world including both coasts of Canada. On the east coast they occur in Newfoundland and throughout the Maritimes (Clapp 1936, Bousfield 1960, LaRocque 1953, M'Gonigle 1925). *Teredo navalis* is especially common in the southwestern Gulf of St. Lawrence and particularly in bays and estuaries, where mean water temperatures are higher than average.

Shipworms are bivalve molluscs of the family Teredinidae. In this family shells in the adults are restricted to jaw-like structures at the anterior end which are used in boring into wood. Larval *Teredo*, which resemble larvae of other molluscs, settle on wood and bore in using their shells. As the animal grows the body elongates, with the burrow being enlarged by the shells and lined with shell material. The siphons and a pair of feather-like appendages, the pallets, remain attached to the wood at the site of entrance. Shipworms derive their food from both plankton in the water circulated through the siphons and from the wood, (Lane 1951, Johnson 1949). They can digest cellulose but obtain nitrogenous food mainly from the plankton.

Breeding of *T. navalis* has been studied at Ellerslie by Sullivan (1948). She found that the larvae, which are released as such into the water by the adult, were present continuously in the water of Malpeque Bay from the beginning of June to early September. In warmer water the breeding season is longer. Richards (1943) found breeding from May to October in North Carolina. The breeding season in colder localities would, no doubt, be shorter.

T. navalis can live at salinities from about 5‰ up to full salinity although activity is reduced below 9‰. Much lower salinities including fresh conditions can be tolerated for short periods (M'Gonigle 1925, Blum 1922, Kofoid et al 1927). Blum (1922) found that *T. navalis* could survive 21 days in fresh water and 22 days in moist air. Shipworms can, therefore, live well up estuaries, particularly if the salinity is variable.

T. navalis occurs mainly in areas where temperatures range from 5°C to 30°C with an optimum and approximate breeding range from 15 to 25°C (Bavendamm and Schmidt 1948, Nelson 1925, 1928). M'Gonigle (1925) who studied shipworm distribution in the Maritimes did not find Teredo where mean summer temperatures were below 13°C. However, it seems certain that Teredo can survive temperatures at or a little below zero for prolonged periods since they are common in many places in the Maritimes where such temperatures occur. Teredo may, therefore, be expected anywhere where summer temperatures rise high enough for breeding.

Shipworms and other marine borers have undoubtedly been passively spread to suitable locations throughout the world in wooden ships. Most authorities agree that the only species found in the Maritimes is Teredo navalis.

Shipworms can do very extensive damage to wood in a short period. Adults and their burrows grow to over one foot in length but where infestation of wood is heavy and competition for space occurs, specimens are usually much smaller than this. In the Maritimes, wooden structures can be completely destroyed in a single season of exposure. This is particularly true of soft woods. Hard woods stand up much longer but eventually are destroyed.

Many methods have been employed to protect wood against shipworm and other marine borer attack. Wood used in oyster farming equipment has for many years been protected with a thick mixture of tar, copper oleate and stove oil (Needler 1941). Another fairly effective treatment consists of the deposition of copper hydroxide within the surface layers of the wood by the reaction of copper sulphate soaked wood with caustic soda. The only really effective protection has been complete metallic sheathing. Coating with paint containing copper compounds is, however, good protection for a short period. In areas of serious attack, paint must be applied twice each season. Once in the wood, shipworm can be killed with sodium arsenite in low concentrations but application is very difficult.

All the forementioned methods suffer from one or more obvious disadvantages. Cost, difficulty of application, and vulnerability of a surface layer to damage and subsequent lack of protection are paramount amoung these drawbacks.

When the effectiveness of a dilute solution of the tin compound, Bis(Tri-n-Butyltin) oxide, in mineral spirits was first cited by M and T Chemicals as a general protection for wood against marine borer attack and even rot, its advantages were at once apparent. (M and T Sheet 226, May 1962). bioMeT TBTO, as the product is Trademarked, is claimed to have a tremendous affinity for cellulose, a property believed to be based on adsorption. This property, combined with the thin clear nature of the solution in mineral spirits, and its insolubility in water should ensure good penetration into wood with negligible post-application leaching. In addition dilutions as used would be relatively cheap to produce and apply.

With these possible advantages in mind it was decided to test bioMeT TBTO at Ellerslie as a general preservative for wood used in marine construction, with particular emphasis on protection against T. navalis attack.

Material and Methods

General

TBTO has been applied to various soft and hard woods in dry and green conditions at concentrations up to 2% in mineral spirits (Varsol and Irsol) and kerosene. Both brush and dip methods of application have been used. Exposures have been for one and two year periods.

As well as the test blocks used in these trials, the material has been applied to oyster rearing trays, stakes, boats and other general equipment.

Tests have been carried out to check for possible adverse biological effects on oysters. In addition biological observations have been made to check Teredo attack in relation to depth and season at Ellerslie.

Test Block methods

Test blocks were cut 2 x 4 x 10 inches for coniferous (soft) wood and 2 x 2 x 10 inches for hard woods except in 1963 when 2 x 2 x 6 inch hard wood blocks were used.

1963. Tests in 1963 were preliminary in nature. Spruce and maple, both planed, were used. Each wood had one block brushed and one dipped for 5 min. at each of the following concentrations of TBTO in Varsol 0.5%, 1.0%, 2.0%. Two untreated blocks of each wood were included as controls. Blocks were also treated with paint only and with paint plus 0.5% and 2.0% TBTO. These blocks were suspended from spat collector floats to a depth of 2-3 ft. in Smelt Creek.

1964. Block tests carried out in 1964 were designed to test four concentrations of TBTO, 2.0%, 1.0%, 0.5% and 0.2%, on three woods, green spruce, dry pine and dry maple, each treated by brush and dip. For 1964 and subsequent tests dip time was reduced to 1 minute. This experimental design required 24 blocks, plus controls for solvent (Varsol) only and untreated wood. To increase useable results it was decided to include the effect of depth in the test. The blocks were exposed on two frames (Fig. 1) each consisting basically of four horizontal rows each of eight blocks. The frame was weighted to hang vertically in the water. Each row on the frame included at least one block at each concentration, at least two blocks of each kind of wood, both applications and two controls. Duplicate frames were made up, one hung in Smelt Creek and one in Paugh's Creek. These frames were set out on May 12 and raised on Sept. 9.

Additionally a vertical series of 14 untreated blocks spaced on a 6 ft. bar was exposed in 6 ft. of water at mean low water in Smelt Creek to check vertical distribution of attack, and a horizontal bar was also hung at the 1.5 feet level carrying control blocks and two blocks that were exchanged and examined every two weeks for seasonal attack studies.

1965. Block tests in 1965 were an extension of those performed in 1964 and were also planned to test new theories regarding effects of TBTO. The two frames used in 1964 were re-used but both were hung in Smelt Creek.

All unattacked blocks from the 1964 tests were re-exposed, this amounted to 33 blocks which were spread over the two frames. Remaining spaces were filled with untreated controls (11 blocks), dry spruce blocks dipped in 1% TBTO and wrapped in ¼" mesh galvanized wire cloth (10 blocks) and dry spruce blocks dipped in 1% TBTO (10 blocks). Additional untreated controls (9 blocks) were hung on a vertical bar. The exposure period was June 4 to Oct. 7.

1966. All the original 1964 blocks re-exposed in 1965 and showing no or light shipworm attack were re-exposed in 1966. The 32 blocks tested were hung from a single frame at the Smelt Creek exposure site. Blocks were exposed from May 12 to Dec. 15.

Tests on General Equipment

1964. Many articles of general wooden equipment used in sea water were treated with ½% TBTO in Irsol, these included stakes, boats and oyster trays. In the case of the oyster trays, controls of normal tar-treated trays were used and all oysters in the trays were measured at the start and end of the season. Condition index was determined for oysters in control and treated trays.

In addition several lobster traps were treated with 1% TBTO in Irsol by the Fisheries Research Board, Lobster Investigation, St. Andrews, and fished with normal tar-treated traps in the Northumberland Strait fishery off Miminigash, P.E.I.

1965. As in the previous year various articles of oyster culture equipment were treated with TBTO. The solution used was 1% in Irsol.

In addition a complex experiment to investigate the possible effects of TBTO, solvents, galvanized wire mesh of two sizes and plastic mesh on oysters was carried out. This test involved 16 trays with the combinations of treatments shown in Table 1. Oysters in the trays were measured at the beginning and end of the season and condition index determinations were made at the end. In addition observations on fouling, shell characteristics, etc. were made.

1966. Wooden articles, not in direct contact with oysters were treated with TBTO as in previous years.

Laboratory Experiments

In simple laboratory experiments, oysters were held in running water in which wooden blocks soaked in 1% TBTO in Varsol were suspended and the effect of wood blocks treated as above and Varsol only controls were tested on developing oyster embryos.

Results

1963 Block Tests

None of the blocks treated with TBTO in 1963 showed damage by shipworm. Control blocks were extensively attacked. Results for paint only and paint plus TBTO were inconclusive since some paint-only blocks remained unattacked.

All the blocks showed extensive algal fouling and some bryozoan fouling.

1964 Block Tests

1964 tests were set up to check if concentrations lower than those used in 1963 would be effective and to provide a large series of test blocks and controls to give adequate results and provide material for re-exposure.

Detailed results are presented in Table 2. Results may be summarized as follows: The green spruce used in the tests was not completely protected even by 2% brush or dip treatments (blocks 6, 24, 30, 48) but attack was light in all spruce blocks dipped in solutions of 1 and 2%. Brushing was much less effective for this green spruce than dipping (eg. blocks 7, 22). Both pine and maple which were dry when treated were free from attack when treated by either brush or dip at concentrations over 0.2%. At 0.2% some light attack resulted in both dipped and brushed blocks (blocks 20, 43, 44), although most blocks receiving such treatment escaped attack (blocks 1, 2, 19, 25, 26).

All Varsol only controls and untreated controls showed virtually complete destruction by Teredo sp. This included the vertical series set out to determine differences of distribution of attack with depth.

Table 3 details results of the experiment to determine season of attack. Blocks were attacked from early July to approximately late August; this period corresponds roughly to that when water temperatures exceeded 18°C.

1964 Tray Tests

Trays treated with a 0.5% solution of TBTO in Irsol showed no damage by shipworm and in addition, mussel fouling was greatly reduced and confined to the tray wire. Observations on oysters held on trays treated with TBTO and compared to similar ones growing on tarred trays showed that specimens were growing more slowly on TBTO treated trays and in addition showed gross shell differences. Shells of oysters from treated trays had thick edges and a heavy deposition of chalky shell material, in addition condition index of oysters in a treated tray was a little lower than the control. Unfortunately the cause of the effect could not be determined with certainty since the mesh on control and treated trays differed. These differences in tray mesh could alter water circulation, and consequently food supply, around oysters.

1965 Block Tests

1965 block tests were designed primarily to re-expose 1964 blocks which resisted shipworm attack and to answer questions regarding possible interaction on combined action of TBTO and galvanized wire. In addition several blocks treated with the CuOH method, described earlier, were included.

Results are presented in Table 4. Blocks were set out June 4 and raised October 7. It is evident that protection for at least two years is afforded by 0.5% or more, dip or brush with TBTO. The only two year old block to show attack enough to weaken the wood was #17. Attack in the other blocks took the form of few, tiny, very shallow burrows without live shipworm. The moderately attacked block, #17, as well as the lightly attacked ones, #'s 1, 7 and 33, were all spruce blocks which were green when treated in 1964. Other blocks showing slight attack were mostly hardwood treated at 0.2%, or pine treated at 1% or less.

New blocks consisted of 20 spruce blocks dipped in 1% TBTO, 10 being wrapped with tray wire. None of these blocks showed any shipworm attack. All untreated controls were virtually completely destroyed.

In regard to fouling of test blocks, it was found that controls were extremely fouled with mussels on the top row of frames. General fouling was extremely heavy on all controls but light on 1965 1% dip blocks and extremely light on dip plus galvanized wire blocks. Mussels only set heavily on controls, lightly on 1% dip and not at all on dip plus wire. CuOH treated blocks were less fouled than controls but mussels and other organisms did settle on them to some extent.

Two year old TBTO blocks showed average general fouling but reduced mussel fouling. Two of five blocks treated by the CuOH method showed moderate attack by shipworm.

Block tests gave no evidence of any differences in Teredo activity at different depths.

Season of attack was not monitored in 1965 but observations showed it to be average. Water temperatures in the test area were over 18°C from mid June until the end of August. Vigorous attack would be expected during this period.

1965 Tray Tests

As outlined above the tray test experiment was complex. Detailed results are presented in Tables 5-9.

Table 5 presents observations on shipworm attack and general fouling on the trays. In summary there were no shipworm in the heavy lumber of any treated tray including those exposed for a second year. Several trays had shipworm in the thin slats securing the wire. These slats are subject to heavy abrasion and possibly lost parts of the surface wood containing the chemical.

Fouling of these trays was variable but in general the wire was moderately to heavily fouled with mussels. Plastic mesh showed more fouling than the wire, it being fouled so extensively that little water exchange could take place. Wood in treated trays had no mussel set but showed average algal fouling. It was notable that trays 2 and 3 were less heavily colonized by mussels than the other trays.

Table 6 presents observations on the fouling on oysters themselves and general data on the appearance of oysters. Fouling patterns in general followed that of the trays.

Observations on the shell characteristics and condition of the oysters are presented in Tables 7 to 9, Table 7 being a general summary of these observations. As shown in Table 8 growth was very variable in treated trays, varying from very high in tray 4 to almost none in tray 12. The mean growth in treated trays was 9.04 mm. (trays 1-13) and in non-treated trays 12.3 mm. Table 8 also presents details of the condition index of these tray oysters. Condition in the three non-treated trays was average for the river with a mean of 64.0 units. On the other hand, condition in treated trays although varying from 61.5 to 109.9 units, had a mean value of 83.7 units and was much above average for the river and the high values extraordinarily high. Evidently condition of oysters on TBTO treated trays was increased over normal; in several cases this was combined with excellent growth, (eg. trays 2 and 4). Table 9 shows characteristics of upper valves of oysters from experimental trays which we used to estimate shell thickness changes. Weight of shells gives a good estimate of total size, and relative thickness is given by the last column derived from the formula 10 x thickness (mm)/Length (mm). It is evident that proportional shell thickness (10 T/L) is greater in oysters from treated trays, no value being as low as that for the controls. The mean value of this statistic for oysters from treated trays was 1.07 whereas that from the controls was 0.60.

In summary oysters on treated trays showed variable but approximately normal growth, increased condition index and increased relative shell thickness.

1966 Block Tests

The 1966 tests were a continuation of those on the blocks treated in 1964. All but one block exposed in 1965 were re-exposed. Re-exposed blocks consisted of 17 that had remained attack free for two seasons of exposure and 15 showing small shipworm burrows limited to the surface of the wood. (Table 4, Blocks 1-16 and 18 to 33).

Results are presented in Table 10. Blocks are numbered in order of the effectiveness of the treatment. As this was the final years exposure all blocks were cut across and the percentage of unattacked wood (by area of cross section) measured. Only one hardwood block brushed with 2% TBTO remained entirely attack free. However, all pine and hardwood blocks treated with a 2% solution had at least 80% of their substance unattacked. Shipworm burrows in these blocks were mainly small and in the immediate surface layer. Treatments at less than 2% showed a steadily decreasing effectiveness modified to some extent by the type of wood. As previously, hardwood was attacked least followed by pine and spruce. Two of the three remaining spruce blocks which were green when treated were almost totally destroyed.

Controls were completely destroyed.

Fouling on test blocks showed little difference from controls for those treated with less than a 2% solution. On blocks treated at 2%, fouling was somewhat reduced. Some mussels (<u>Mytilis edulis</u>) on these blocks showed stunted growth but the majority appeared normal.

Lobster trap tests

Traps treated with 1% TBTO in Irsol and fished with normally (tar) treated traps in Northumberland Strait caught a normal number of lobsters and showed no shipworm attack. This investigation was carried out by the lobster group at St. Andrews who have full results.

Laboratory Experiments

An experiment to check the effect of wood treated with TBTO in Varsol on developing oyster eggs proved inconclusive when the Varsol-only control series proved to be lethal.

Oysters held 2½ months in running water in which wood treated with 1% TBTO in Varsol was suspended showed no apparent ill effects.

Discussion

Treatment

The tests have checked the effectiveness of concentrations of TBTO from 0.2 to 2% dissolved in Varsol, Irsol and Kerosene and applied by brush and dip. There is no evidence of any differences in effectiveness with the three solvents used. It would be expected that any proprietary brand of mineral spirits or light oil would be a suitable solvent for use.

The percentage of TBTO in the solvent in which it is applied does, however, have an effect on the degree of protection against shipworm attack. As shown in Table 2 even 0.2% was effective protection on dry wood exposed one year and gave considerable protection for a two year exposure (Table 4). Only a 2% dip treatment on blocks gave complete protection for a two year exposure. No treatment proved completely effective for three years (Table 10), although dry blocks treated at 2% showed only superficial damage. The differences in protection afforded to green and dry blocks showed the importance of at least using fairly dry wood. Neither the solvents used nor TBTO are appreciably soluble in water and penetration of the green blocks could not be expected. TBTO has a tremendous affinity for cellulose, a property believed to be based on adsorbtion (M and T, 1962) but its solubility characteristics prevent contact with cellulose in wet wood. The extremely low solubility of TBTO in water must account for the long life of the treatment. Results from blocks treated at low concentrations and exposed for two years suggest that there was some loss of TBTO from the extreme surface of the wood, where <u>Teredo</u> were able to start their burrows. Sufficient TBTO evidently remained within the blocks to limit boring to the extreme surface. The fact that this chemical is readily soluble in mineral spirits and light oil enables deposition well into wood which readily absorbs these solvents. Deep penetration also gives the wood protection even where it is exposed to light mechanical damage.

The results do show a greater effectiveness of dip applications, particularly on green wood, however, brush applications appeared to be almost equally effective under normal conditions.

The results suggest that a 1 or 2% solution of TBTO brushed on or dip applied would be adequate for routine use.

Two years appears to be the maximum safe exposure time for wood exposed under local conditions. However, a 2% treatment on dry wood did prevent serious damage even in the third season of exposure.

As pointed out by M and T (1962) TBTO at low concentrations is also an effective fungistat and is bactericidal with many species. It is also said to be effective against gribbles (Limnoria) the other marine borers found in our waters. Application of TBTO therefore can be expected to have a general preservative effect on wood. Our tests have shown its effectiveness in the reduction of general marine fouling on wood to which it is applied. Limited tests with the addition of TBTO to marine paints and with commercial paints formulated with TBTO or a similar compound (tributyl tin fluoride) show that this greatly reduces fouling. M and T (1962) point out that mixing TBTO with paint greatly reduces its activity and that 15% TBTO is required in paint to control fouling.

Toxicity of TBTO

The effectiveness of TBTO relies at least in part on its toxicity to various organisms. The acute oral LD_{50} (dose required to kill 50% of test animals) for rats is about 200 mg/kg and for rabbits 11,700 mg/kg, (M and T 1962). Thus the undiluted chemical (95%) is quite poisonous and may be fatal if swallowed. The chemical (95%) is also a skin irritant and gloves should be worn when handling it undiluted.

As explained in the results peculiar shell morphology appeared on oysters from 1964 test trays. These 1964 trays also showed almost complete absence of mussel set although such were heavy on normal trays. Unfortunately other uncontrolled variables were present in that year and no correlations could be shown. The absence of mussels was also peculiar, especially since many normal mussels were present on treated test blocks. A few mussels on blocks exposed in 1966 appeared stunted. It was therefore considered that some condition peculiar to trays might be responsible. Since we knew that zinc from galvanized wire was readily picked up by oysters (Drinnan 1966) and that TBTO was a tin compound, it was considered that the oysters may also collect tin. Perhaps an interaction or combined action of these two metals could account for the observed effects. To test this hypothesis a block test in 1965 compared fouling on wooden blocks dipped in 1% TBTO and wrapped with galvanized wire with that on blocks just dipped in 1% TBTO. It was found (see results and Table 4) that there was no shipworm attack in either set and that fouling was much less on the wire wrapped blocks. Additionally the wrapped blocks showed no mussel set at all whereas there was a light set on unwrapped blocks. It is therefore concluded that the presence of zinc coated wire does in some way increase the toxicity and effectiveness of TBTO treatment. No explanation of this is offered; samples of oysters from treated trays have been submitted for analysis of the tin content of their meats but no results are available yet.

1965 experiments with trays attempted to clear up questions posed by the 1964 tests. It was clear from these experiments that growth was not affected by the TBTO. Growth was highly variable among the treated trays (see Table 8), but was definitely reduced on trays with plastic mesh. Mean growth on 4 trays with plastic mesh was 4.7 mm and differed significantly from that on 12 trays with galvanized mesh of ¼ and ½" which was 11.32 mm ($P= <0.01$). The plastic mesh is thick, has openings of only about 1/8" and it seems probable that it curtails normal water exchange and hence reduces the amount of available food. Differences in growth rate between ¼ and ½" mesh were small, the mean for three ½" trays being 9.3 mm and for nine ¼" trays 12.0 mm. These means are not significantly different ($P=>0.1$). Although differences between mean growth rates on galvanized mesh are not large, it is worth observing that growth rates within a tray were quite uniform. It is probable that variables not measured here were affecting growth.

The thickening of shell in oysters in TBTO treated trays is quite evident, as explained above in the results. The cause of this is not known but there still remains some evidence that a combination of zinc and tin could play a part. Mean relative shell thickness (10 x thickness/length) was least for untreated trays being 0.6 as compared to 1.07 for treated. These differences are significant ($P=<0.01$). However, among the treated trays there were three without zinc and relative shell thickness was less than average on these being 0.87 compared to trays with TBTO + zinc where it was 1.14 (difference significant at 95% level $P= 0.05$). One further series of two trays could be expected to have the combined effect reduced, these were the re-exposed trays. Again these showed reduced relative thickness. If the 2 trays with reduced effect caused by two year exposure are grouped with those with plastic mesh the mean relative thickness is 0.90 compared to 1.19 for the 8 trays with the full combined treatment. These differences are significant ($P=<0.01$). Evidently the effects of TBTO on oyster shell growth are increased in the presence of zinc.

As explained in the results mean condition of oysters on treated trays was higher than that for controls. The reason for this effect is a mystery. It is possible that the TBTO treatment did decrease general tray fouling enough to cause a significant increase in tray water exchange or that treatment inhibited development of a fauna competitive with oysters. The correlation of high condition index with increased relative shell thickness may well be a spurious one as both may be caused by the same factor.

In summary, oysters on TBTO treated trays do show differences from controls in that condition and relative shell thickness are both increased. The fact that growth on many treated trays was also good prompts the conclusion that changes that do occur are not entirely harmful. There is evidence that there is some biological interaction between galvanized wire and TBTO which enhances the effects of TBTO; this effect should be further investigated.

Mussels used in a different experiment and held on TBTO treated trays showed considerable mortality. Although the experiment was not controlled in respect to TBTO treatment, it is assumed that this chemical played a part in this mortality.

It is concluded that, in general, TBTO treatments should not be used for wood in direct or almost direct contact with commercial shellfish as shell changes and mortality may occur.

Recommendations for the use of TBTO

All wood to be used in marine locations and not in direct contact with commercial shellfish where attack by shipworm (T. navalis) or gribble (Limnoria sp.) occurs would benefit by treatment with TBTO. The following methods are recommended.

i) All new wood or wooden structures however they are to be finished should be at least surface dry and brushed or dipped in a 1% to 2% solution of TBTO in mineral spirits or a commercial wood preservative containing TBTO. Dipping is preferable where possible. If wood is to be worked after treatment all newly exposed surfaces should be touched up.

ii) Where the wood will be finished by painting (eg in boat hulls), the paint can be applied as soon as the preservative is dry. Fouling can be reduced by adding 15% TBTO to paint or by using a commercial paint containing TBTO or related compounds. Such treatment will protect the hull against marine borers even if the paint is chipped or abraded. Re-painting with a similar paint should be annual. (A report on paint containing organotin compounds will follow). Chipped or abraded areas where bare wood is exposed should be touched up with preservative. Preservative will have little or no beneficial effect where bare wood is not exposed.

iii) Wood to be used unfinished should be thoroughly dried and re-treated by brush or dip with preservative every two years.

iv) Equipment or structures already in use and treated with other preservatives or paints can not readily be treated with TBTO. The best compromise would be painting with a paint containing TBTO.

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Fig. 1. Test Block Frame.

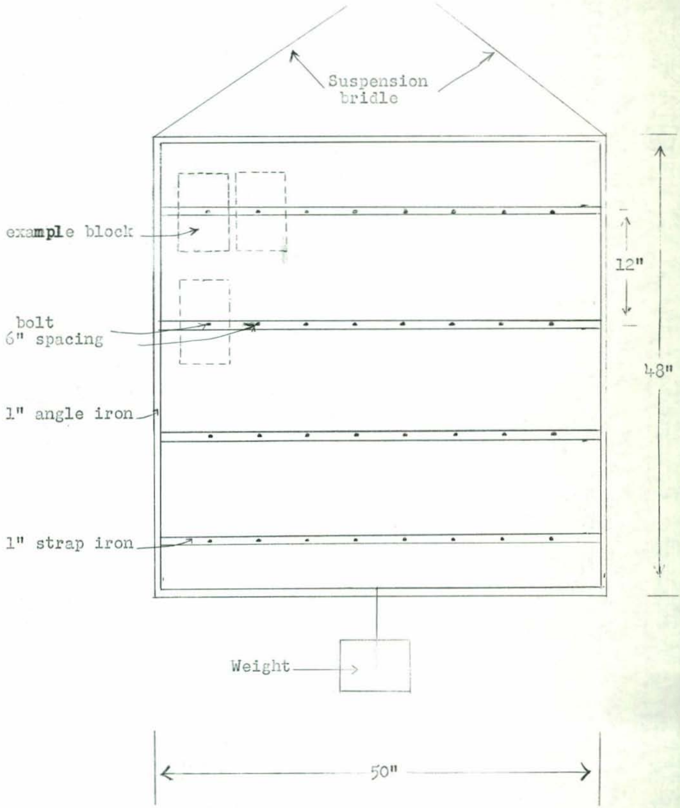

Table 1

1965 Oyster Tray Test - Tray Treatments

TBTO Solution	Mesh	No. of Trays	Remarks
1% in Kerosene	¼" galv.	2	Re-treated from 1964.
1% in Kerosene	¼" galv.	2	New trays.
1% in Kerosene	½" galv.	1	New trays.
1% in Kerosene	Plastic	1	New trays.
1% in Irsol	¼" galv.	1	Re-treated from 1964.
½% in Irsol	¼" galv.	1	Re-exposed from 1964.
½% in Irsol	½" galv.	1	Re-exposed from 1964.
1% in Irsol	¼" galv.	1	New tray.
1% in Irsol	Plastic	1	New tray.
1% in Varsol	¼" galv.	1	New tray.
1% in Varsol	Plastic	1	New tray.
Tarred tray	¼" galv.	1	New tray.
Tarred tray	Plastic	1	New tray.
Varsol only	½" galv.	1	New tray.

Table 2

Results of 1964 Tests on Wooden Blocks

Treated with TBTO for Protection against Shipworm attack.

Blocks on frames in Bideford River and Smelt Creek
Set out 12 May - Raised November 9.

Block No.	Treatment	Wood	Frame #	Row	Attack
1	0.2% Dip	Pine	1	1	-
2	0.2% Dip	Maple	1	1	-
3	0.5% Brush	Spruce	1	1	+
4	1.0% Dip	Spruce	1	1	+
5	1.0% Brush	Maple	1	1	-
6	2.0% Brush	Spruce	1	1	+
7	0.2% Brush	Spruce	1	2	+++
8	0.5% Brush	Pine	1	2	-
9	0.5% Dip	Maple	1	2	-
10	1.0% Brush	Pine	1	2	-
11	2.0% Brush	Maple	1	2	-
12	2.0% Dip	Pine	1	2	-
13	0.2% Dip	Spruce	1	3	++
14	0.5% Dip	Pine	1	3	-
15	0.5% Brush	Maple	1	3	-
16	1.0% Dip	Pine	1	3	-
17	2.0% Dip	Maple	1	3	-
18	2.0% Brush	Pine	1	3	-
19	0.2% Brush	Pine	1	4	-
20	0.2% Brush	Maple	1	4	+
21	0.5% Dip	Spruce	1	4	-
22	1.0% Brush	Spruce	1	4	+++
23	1.0% Dip	Maple	1	4	-
24	2.0% Dip	Spruce	1	4	+
25	0.2% Brush	Pine	2	1	-
26	0.2% Dip	Maple	2	1	-
27	0.5% Dip	Spruce	2	1	++
28	1.0% Brush	Spruce	2	1	+
29	1.0% Dip	Maple	2	1	-
30	2.0% Dip	Spruce	2	1	+
31	0.2% Dip	Spruce	2	2	++

Table 2 (Continued)

Block No.	Treatment	Wood	Frame #	Row	Attack
32	0.5% Dip	Pine	2	2	-
33	0.5% Brush	Maple	2	2	-
34	1.0% Dip	Pine	2	2	-
35	2.0% Dip	Maple	2	2	-
36	2.0% Brush	Pine	2	2	-
37	0.2% Brush	Spruce	2	3	++
38	0.5% Brush	Pine	2	3	-
39	0.5% Dip	Maple	2	3	-
40	1.0% Brush	Pine	2	3	-
41	2.0% Brush	Maple	2	3	-
42	2.0% Dip	Pine	2	3	-
43	0.2% Dip	Pine	2	4	+
44	0.2% Brush	Maple	2	4	+
45	0.5% Brush	Spruce	2	4	++
46	1.0% Dip	Spruce	2	4	+
47	1.0% Brush	Maple	2	4	-
48	2.0% Brush	Spruce	2	4	+
49-51	Nil	Spruce	1+2	1-4	+++
52-53	Nil	Pine	1+2	1-4	+++
54-56	Varsol only	Spruce	1+2	1-4	+++
57-60	Varsol only	Pine	1+2	1-4	+++
61-64	Varsol only	Maple	1+2	1-4	+++
65-78	Nil	Spruce	3	Vertical	+++
79-82	Nil	Spruce	4	Horizontal	+++

KEY: - Nil, + Light, ++ Moderate, +++ Complete destruction.

Notes: M. edulis fouling abundant on top and second rows (rows 1 and 2). B. improvisus common on third and bottom rows (rows 3 and 4). Algal fouling general.

Table 3

Seasonal Exposure Tests 1964

Exposure period	Observations
May 12-26	No *Teredo* attack.
May 26-June 9	No *Teredo* attack.
June 9-23	No *Teredo* attack.
June 23-July 7	No *Teredo* attack.
July 7-21	*Teredo* attack - holes to 1/8" deep.
July 21-August 4	Many *Teredo* holes - mean conc. 12.8/cm2 - holes 1/8" deep.
August 4-18	Many *Teredo* holes, estimated heavier set than last two weeks and holes ¼" deep.
August 18-Sept. 22	A few *Teredo* set - 20 per block. Large size suggests set early in this period.
Sept. 22-October 13	No *Teredo* attack.
Oct. 13-November 9	No *Teredo* attack.

Table 4

Results of 1965 Tests on Wooden Blocks Treated with

TBTO for Protection against Shipworm attack.

Blocks on frames in Bideford River.
Set out June 4 - Raised 7 October, 1965.

A. Blocks treated in 1964 - Second year of exposure.

Block No.	Treatment	Wood	Frame #	Row	Attack
1	0.5% Dip	Spruce	1	1	+
2	0.2% Brush	Hardwood	1	1	+
3	1.0% Brush	Hardwood	1	1	-
4	2.0% Dip	Hardwood	1	2	-
5	0.2% Dip	Hardwood	1	2	-
6	1.0% Dip	Pine	1	2	+
7	2.0% Brush	Spruce	1	2	+
8	2.0% Brush	Pine	1	3	-
9	0.2% Brush	Hardwood	1	3	+
10	1.0% Dip	Hardwood	1	4	-
11	0.2% Brush	Pine	1	4	+
12	0.2% Dip	Pine	1	4	+
13	1.0% Brush	Hardwood	2	1	-
14	0.2% Brush	Hardwood	2	1	-
15	0.5% Dip	Hardwood	2	1	-
16	2.0% Dip	Pine	2	1	-
17	1.0% Dip	Spruce	2	1	++
18	0.5% Brush	Pine	2	2	+
19	1.0% Brush	Pine	2	2	+
20	2.0% Brush	Pine	2	2	+
21	0.5% Dip	Pine	2	2	+
22	2.0% Brush	Hardwood	2	2	-
23	0.5% Brush	Hardwood	2	3	-
24	0.5% Brush	Pine	2	3	+
25	2.0% Dip	Pine	2	3	-
26	0.2% Dip	Pine	2	3	+
27	0.5% Dip	Hardwood	2	3	-
28	2.0% Brush	Hardwood	2	4	-
29	0.5% Dip	Pine	2	4	+

Table 5

Observations on Experimental TBTO Trays - 1965

Set out 25 May - Raised October 5, 1965.

Fouling on Trays and *Teredo* attack

Tray #	Treatment* Code	Comments
1	KB4R	No Shipworm. Bottom heavily matted with small mussels. Inside with a few mussels. Starfish in and out.
2	KB4R	No Shipworm. No mussels at all on wire, few on wood. Little other fouling. Very clean.
3	IB4R	No Shipworm. Relatively clean. Very few mussels. Many hydroids. Sponge on mesh.
4	IB4E	No Shipworm. Wire moderately fouled with normal mussels.
5	IB2E	Shipworm in two slats, none in heavy lumber. Bottom heavily fouled with mussels of mixed size. Starfish abundant in and out.
6	KB4N	No Shipworm. Bottom heavily matted with mussels of mixed size, with almost no mesh visible. Starfish abundant in and out.
7	KB2N	No Shipworm. Extensive mussel fouling in and out. Abundant starfish.
8	IB4N	Shipworm in two slats - none in heavy lumber. Bottom fouled with larger mussels. Starfish in and out.
9	KB4N	No Shipworm. Mussels fairly heavily settled on bottom and very small. Abundant starfish in and out.
10	VB4N	No Shipworm. Bottom very heavily matted with very small mussels. Many small starfish inside.
11	IBPN	No Shipworm. Bottom fairly heavily fouled with small mussels and many sea squirts.
12	KBPN	No Shipworm. Bottom matted with tiny mussels. Few starfish.
13	VBPN	No Shipworm. Bottom matted with tiny mussels. Few starfish.
14	OTPN	Shipworm in slats. Bottom matted with tiny mussels. Starfish common in and out.
15	OT4N	No Shipworm. Bottom matted with tiny mussels.

Table 6

Observations on Experimental Oysters from TBTO Trays

Set out 25 May - Raised October 5, 1965

Fouling on Oysters and General Observations

Tray #	Treatment* Code	Comments
1	KB4R	Moderate mussel fouling, regular oyster growth with little stunting.
2	KB4R	Very few mussels. Good growth with a little stunting.
3	IB4R	Very few mussels. Moderate stunting of oyster shells. Shells quite brittle.
4	IB4E	Heavy mussel fouling. Mussels and limpets appear larger than in most trays.
5	IB2E	Few mussels but general fouling eg. with hydroids worse than most lots. Fairly good regular oyster growth.
6	KB4N	Moderate mussel fouling. Some stunting but good growth.
7	KB2N	Moderate mussel fouling and some limpets. Some stunting but good growth.
8	IB4N	Many small mussels. Oysters stunted with very thick edge.
9	KB4N	Moderate mussel fouling. Good growth with prominent dorso-ventral crimping.
10	VB4N	Dense mussel fouling. Good growth with some crimping at edge.
11	IBPN	A few small mussels. Growth of oysters fair and regular although stunting is noticeable.
12	KBPN	Very few mussels. Higher mortality. Poor growth.
13	VBPN	Very few mussels and these small. Oysters stunted.
14	OTPN	Little mussel fouling. Slight oyster stunting.
15	OT4N	Moderately heavy fouling with small mussels.
16	VO2N	Small mussels in dense mat over oysters.

General Observations: "Stunting" is used to describe oysters showing thickening right up to the edge of the shell combined with poor growth.

"Crimping" is used to describe oysters showing stunting which has been followed by some normal growth thus giving an oyster with a thick centre and thin edge.

For treatment code see tray observation results.

*See Table 5 for code.

Table 7

Observations on Shell Characteristics of Oysters From 1965 TBTO Trays

Set out 25 May - Raised October 5, 1965

Tray #	Treatment* Code	Thickened Shell	Chalky Deposits	Growth
1	KB4R	*	* *	* * *
2	KB4R	*	*	* * *
3	IB4R	* *	*	* *
4	IB4E	*	* *	* * *
5	IB2E	-	* *	* *
6	KB4N	* * *	* * *	* *
7	KB2N	* *	*	* *
8	IB4N	*	* *	* *
9	KB4N	*	* *	* * *
10	VB4N	*	* *	* * *
11	IBPN	-	* *	*
12	KBPN	-	-	-
13	VBPN	*	* *	*
14	OTPN	-	*	* * *
15	OT4N	-	*	* * *
16	VO2N	-	*	* * *

Notes:

Thickened Shell	Chalky Deposits	Growth
*** Grossly	*** Cover almost entire shell.	*** 10+mm
** Moderately	** 70% Cover	** 6-9mm
* Slightly	* 50% Cover	* 2-6mm
- Nil	- 20% Cover or less	- <2mm

*See Table 5 for code.

Table 8

Observations on Experimental TBTO Trays - 1965

Set out 25 May - Raised October 5, 1965

Lengths, Growth and Condition Index of Experimental Oysters

Tray #	Treatment* Code	Mean Length (mm) 25 May	Mean Length (mm) 6 Oct.	Total Growth (mm)	Condition Index
1	KB4R	42.5	55.8	13.3	91.2
2	KB4R	41.3	54.2	12.9	105.0
3	IB4R	41.0	50.2	9.2	109.9
4	IB4E	41.5	59.5	18.0	105.3
5	IB2E	42.9	51.2	8.3	70.8
6	KB4N	41.2	50.4	9.2	83.6
7	KB2N	41.9	50.7	8.8	79.4
8	IB4N	39.7	48.3	8.6	78.0
9	KB4N	40.2	50.9	10.7	76.7
10	VB4N	40.1	51.5	11.4	69.1
11	IBPN	43.2	45.3	2.1	78.2
12	KBPN	39.2	40.9	1.7	61.5
13	VBPN	42.9	46.3	3.4	79.0
14	OTPN	42.0	53.6	11.6	69.7
15	OT4N	42.2	56.7	14.5	70.5
16	VO2N	43.1	54.0	10.9	51.8

*See Table 5 for code.

Table 9

Measurements of Characteristics of Upper Valves of Shells from Oysters in TBTO Trays 1965

Tray #	Treatment* Code	Mean Length mm.	Mean Weight g.	Mean Thickness mm.	10 T/L
1	KB4R	51	8.1	5.9	1.2
2	KB4R	49	7.1	5.3	1.1
3	IB4R	43	5.4	5.7	1.3
4	IB4E	51	7.8	5.4	1.1
5	IB2E	53	7.5	4.2	0.8
6	KB4N	50	9.1	6.9	1.4
7	KB2N	47	6.7	6.0	1.3
8	IB4N	48	7.0	5.3	1.1
9	KB4N	48	5.9	5.4	1.1
10	VB4N	42	5.0	4.3	1.0
11	IBPN	48	5.7	4.3	0.9
12	KBPN	35	2.4	2.5	0.7
13	VBPN	46	5.4	4.7	1.0
14	OTPN	46	4.3	2.7	0.6
15	OT4N	53	5.2	3.2	0.6
16	VO2N	51	5.0	3.1	0.6

*See Table 5 for code.

Table 10

Results of 1966 Tests on Wooden Blocks
Treated with TBTO for Protection against Shipworm Attack

(Listed in order of effectiveness of treatment.)
Blocks on frame in Bideford River set out May 12,
Raised December 16.

Block #	Treatment	Wood	Attack	% Good Wood
1	2% Brush	Hardwood	-	100
2	2% Brush	Hardwood	+	95
3	2% Dip	Hardwood	+	95
4	2% Dip	Hardwood	+	95
5	2% Brush	Pine	+	90
6	2% Brush	Pine	+	85
7	2% Dip	Pine	+	80
8	2% Dip	Pine	+	80
9	1% Brush	Hardwood	+	80
10	0.5% Brush	Pine	+	75
11	1% Brush	Hardwood	+	70
12	0.5% Dip	Hardwood	+	70
13	0.5% Brush	Hardwood	+	70
14	1% Dip	Pine	+	65
15	0.5% Dip	Hardwood	+	65
16	0.5% Brush	Pine	+	65
17	0.5% Dip	Spruce	+	65
18	1% Dip	Hardwood	+	60
19	0.5% Brush	Hardwood	++	50
20	0.2% Brush	Hardwood	++	50
21	1% Dip	Hardwood	++	40
22	0.2% Dip	Pine	++	40
23	0.2% Brush	Pine	++	40
24	0.5% Dip	Pine	+++	30
25	0.2% Brush	Hardwood	+++	20
26	0.2% Dip	Hardwood	+++	20
27	0.2% Dip	Pine	+++	20
28	1% Brush	Pine	+++	10
29	0.5% Dip	Pine	+++	10
30	0.2% Dip	Hardwood	+++	10
31	2.0% Dip	Spruce	+++	5
32	2.0% Brush	Spruce	+++	0 (Block disintegrated)