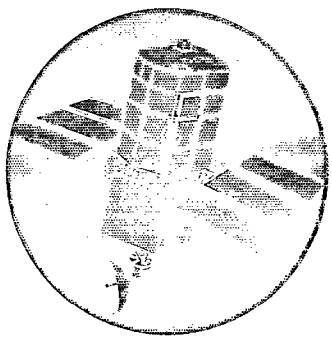
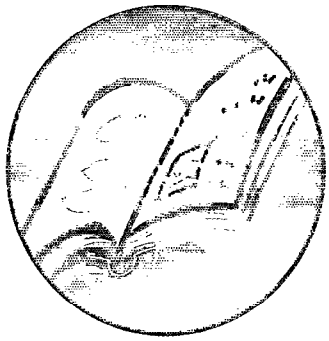
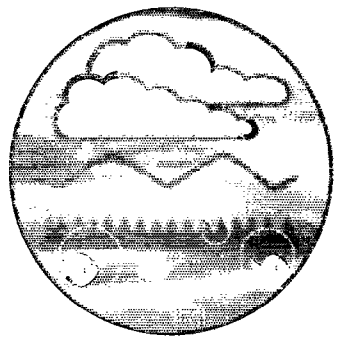
Environmental Problems from Antifouling Agents

Survey of Manufacturers, Chandlers (Suppliers) and Treatment Sites

Research and Development

Technical Report
P215

ENVIRONMENT AGENCY

Environmental Problems from Antifouling Agents

Survey of Manufacturers, Chandlers (Suppliers) and Treatment Sites

R&D Technical Report P215

Research Contractor:

WRc plc

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tel: 01793-865000 fax: 01793-514562 e-mail: publications@wrcplc.co.uk

Publishing Organisation:
Environment Agency
Rio House
Waterside Drive
Aztec West
Almondsbury
Bristol BS32 4UD

Tel: 01454 624400 Fax: 01454 624409

ISBN: 1 873160 74 7

Dissemination status
Internal: Released to Regions
External: Released to Public Domain

Statement of use
This study quantified the nature and scale of the pollution problem posed by antifouling paints containing booster biocides used in the UK waters. The results will be used to prioritise the development of anlaytical techniques and more closely target monitoring activities. The results will assist in the risk assessment of existing antifouling biocides by providing the inputs necessary for exposure modelling.

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EXECUTIVE SUMMARY

Fouling is the successive build up of bacteria, macroalgae, mussels, barnacles and other invertebrates on underwater surfaces. It is a process with negative economic consequences and consequently paints that contain biocides are applied to ship and boat hulls and other underwater structures to prevent or reduce fouling. These paints are known as antifoulants.

Antifoulant paints contain biocides which are released slowly over a period of time minimising fouling. In the past, organotins and copper were used as biocides. However, whilst copper is still used, the legal use of tributyltin (TBT) is now limited to vessels greater than 25 m in length. As a consequence manufacturers have introduced alternative biocides and currently nine booster biocides are approved for use in amateur antifouling products intended for use by amateur boat owners in the UK.

Problems from TBT have been well documented, however the potential for non-TBT booster biocides to cause pollution has not been quantified. The Environment Agency therefore commissioned WRc to perform a study to assess the environmental problems arising from antifouling agents other than TBT. The study will also provide information for the Advisory Committee on Pesticides' review of booster biocides.

A survey of boatyards, chandlers, marina and harbour operators, paint manufacturers and boat owners was performed to identify 1) which antifouling paint brands and products are used in the UK; and 2) concentrations of biocides in antifouling paint products.

The survey indicated that copper(1)oxide is used in the highest quantities followed by diuron, copper thiocyanate, irgarol 1051, zinc pyrithione and dichlofluanid. Using a mathematical model of a marina, concentrations of each of these biocides in marina water were estimated, these ranged from 0.023 - 254 $\mu g l^{-1}$. These values were generally more than an order of magnitude higher than toxicological data for the biocides.

Information was also obtained on: 1) the size and type distribution of leisure craft; 2) numbers of leisure craft in estuaries, harbours and marinas; and 3) the frequency, timing and methods used for antifouling paint application. In the future, by using this information in combination with the product information and the estuary model currently being developed for the UK Health and Safety Executive (HSE) and the Environment Agency, it should be possible to estimate relative inputs and concentrations of biocides in the areas surveyed. This information will help to determine whether further control options are necessary.

KEY WORDS

Antifouling, booster biocide, survey, copper(1)oxide, diuron, copper thiocyanate, irgarol 1051, zinc pyrithione, dichlofluanid

1. INTRODUCTION

When a clean surface is placed in a natural water, macromolecules that are dissolved in the water form a layer on the surface which facilitates the attachment of bacteria to the surface. Protozoa can then settle on the bacterial layer where they may attract larvae of macroalgae, mussels, barnacles and other invertebrates. This process, known as fouling, occurs in both fresh and saline waters and has negative economic consequences. For example, fouling of ships' hulls causes an increase in water resistance resulting in an increase in fuel use and possibly lowering of the ship's performance. Consequently paints that contain biocides are applied to ship and boat hulls and other underwater structures to prevent or reduce fouling. These paints are known as antifoulants.

Antifoulant biocides are applied in paints which form a protective top layer, the biocides are then released slowly over a period of time minimising fouling. In the past, organotins and copper were used as biocides. However, whilst copper is still used, the legal use of tributyltin (TBT) is now limited to vessels greater than 25 m in length.

Some of the common algae (e.g. Enteromorpha sp. and Amphora sp.) are tolerant to copper (ACP, 1995), consequently manufacturers have introduced additional biocides for use on vessels less than 25 m and on certain larger vessels. These biocides are generally used in combination with copper and are termed booster biocides. Currently, nine booster biocides are approved for use in amateur and professional antifouling products, namely:

- zinc pyrithione
- TCMTB (2-thiocyanomethyl-benzothiazole)
- kathon 5287
- TCMS pyridine (2,3,5,6-tetrachloro-4-sulfuronyl pyridine)
- irgarol
- diuron
- dichlofluanid
- chlorthalonil
- zineb

NB: The booster biocides , thiram, ziram and maneb are no longer approved for use although some may be in the supply chain.

In addition to entering the environment through leaching, the biocides can be released into the environment during paint stripping, boat maintenance and paint application. As the biocides are by their very nature toxic to aquatic organisms, there is a potential for antifouling usage to have an effect on non target organisms. The problems associated with the use of the organometallic biocide, TBT are well documented (e.g Smith, 1981, Beaumont and Budd, 1984, Waldock, 1986) and it has been banned from use on smaller vessels. However, there are only limited data on the potential for the other approved biocides to enter the environment and the likely effects of these biocides on non-target organisms.

The Environment Agency therefore commissioned WRc to perform a study to assess the environmental problems arising from antifouling agents other than TBT. The study was desk based and involved a survey of paint manufacturers, chandlers, boatyards, harbour authorities,

marina operators and boat owners to quantify the usage of the different biocides and their likely inputs to the aquatic environment. The study will also provide information for the Advisory Committee on Pesticides (ACP) review of booster biocides.

1.1 Objectives

The overall objective of the study was to investigate and quantify the nature and scale of the potential pollution problem posed by antifouling paints containing booster biocides used by leisure craft in UK coastal waters in order that the Environment Agency can develop suitable analysis techniques and target its monitoring activities more effectively.

The specific aims were to:

1. identify the nature of the problem based on a usage data survey of paints sold by chandlers, marketing companies, approval holders, and used at treatment sites;

2. rank the booster biocides in terms of amount used in order to target monitoring in the environment and future method development; and

3. provide the Environment Agency with information relating to the use and quantities of antifouling biocides in UK waters.

2. GENERAL APPROACH

Antifouling systems can be divided into a number of categories, including: soluble matrix type, insoluble matrix type, ablative or polishing tin free paints, self polishing organotin paints, self polishing tin free paints and non-stick coatings. Different active ingredients are used in each of these paint types and the usage patterns are likely to vary. For example, certain paints may be more effective in freshwater than saline waters; the longevity of the paints (and hence the application rates) will vary; certain paint types are incompatible with certain substrates and leaching behaviour may be different.

There are four main ways in which antifouling biocides can enter the environment, e.g.:

1. during the application of the antifouling paint;
2. leaching from paint on the hulls of vessels;
3. when the paint is removed; and
4. when the paint remnants are discarded.

Moreover, the distribution and usage of antifouling paints can follow a number of pathways (Figure 2.1). Therefore, in order to accurately assess the likely inputs of antifoulants to the environment, the following issues need to be addressed:

- what quantities of each antifouling product are used?
- which biocides are used in which products?
- what are the concentrations of the biocides in each of the products?
- what are the densities of vessels in UK waters?
- how often and when are these vessels antifouled?
- how and where are the vessels antifouled?
- at what rate do the biocides leach from the antifouling paint?

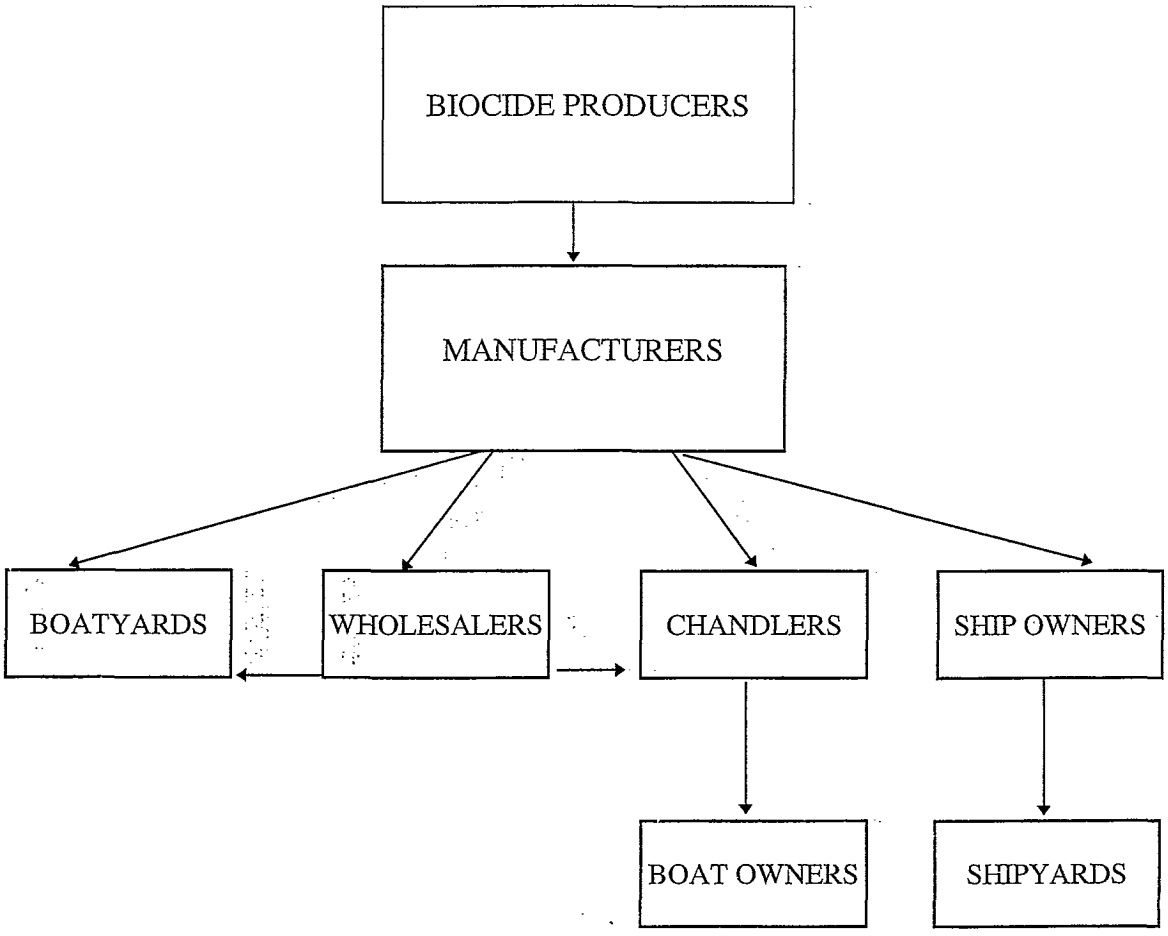

Figure 2.1 Methods for distribution of antifouling paints

A survey of boat owners, boatyards, chandlers, wholesalers, marina operators, harbour operators and manufacturers was therefore required. This was performed in two stages. In the first stage, a pilot study using in-depth interviews was performed, the aim of which was to: 1) identify the type and quality of information that was likely to be available on the usage of antifouling paints; and 2) to provide information to assist in the preparation of survey questionnaires. In the second stage of the project, questionnaires were produced and used to obtain information on antifouling usage around the UK.

2.1 Pilot study

The initial pilot study was performed by representatives of the market research company, General Question (GQ), in January and February 1998 in the Southampton area. In total, two harbourmasters, two boatyards and two chandlers were interviewed face-to-face and interviews lasted around one hour. Questions asked included:

Harbourmasters/Marina Operators

How many boats regularly use the harbour/estuary?

What proportion would you estimate are 25 m and under?

Thinking about the boats that are under 25 m, what different types exist and can you estimate the proportion of each type?

How often do you dredge and how deep do you dredge?

How does the number of boats in the marina change over the year?

What facilities do you have nearby to remove and re-coat antifouling paints?

Who normally strips and recoats the antifoulant?

Chandlers

What brands of antifouling paint do you sell?

What types of antifouling paint do you sell?

What sizes of tin do you sell and which are most popular?

Which colours are the most popular?

Who do you sell the paint to?

How does demand for antifouling paint vary over the year?

What volume of paint do you sell in a year?

Can you tell me where the paint is applied?

Do you know what happens to the paint when it is removed?

Over the past five years have you changed the brands that you sell?

Why do you stock these brands?

Do you know what active ingredients are in the paints?

Who are your suppliers of antifouling paint?

Boatyards

How many boats under 25 m do you antifoul each year?

What are the proportion of the different sizes?

What is the proportion by different type of boat?

Which brands of antifouling paint do you use?

Why do you use these particular brands?

Which colours are the most popular?

Where do you purchase the paint?

Does the antifouling paint you use depend on the type or size of the boat?

If yes - which type of paint do you use for which type of boat?

How often does the same boat get antifouled?

How does demand for antifouling vary over the year?

What methods do you use for antifouling?

What do you do with the antifouling paint you remove?

Do you know what active ingredients are in the paint?

2.2 Full survey

On the basis of the pilot studies, a number of questionnaires (these are given in Appendix A) were produced for surveying chandlers, boatyards, harbour and marina operators and boat owners. Each survey group was surveyed either by telephone or post between January and July, 1998. A summary of the survey strategy used is given in Table 2.1 and specific information for each of the survey groups is detailed below.

2.2.1 Biocides manufacturers

Three biocide manufacturers (Ciba Specialities, Rohm and Haas and Olin Corporation) were contacted to obtain information on the environmental fate, behaviour and effects of the antifouling biocides that they produce. In addition, data were obtained from UK Environmental Quality Standards (EQS), where available.

2.2.2 Paint manufacturers

In the UK there are five main manufacturers of antifouling paints, International, Blakes, Jotun, XM Yachting and Awlgrip. Each of the manufacturers (excluding Awlgrip) were initially contacted by telephone and a visit was arranged to International Paints to discuss the availability of data.

Each manufacturer was asked for a full list of their products and information on the identity and concentrations of active ingredients in each of the products. Information on the leaching rates of the active ingredients and sales volumes for individual products was also requested.

2.2.3 Chandlers

A database of chandlers throughout England and Wales was compiled from the Sail and Power Nautical Almanac (1998). In the first instance, chandlers on the database were contacted by telephone and asked to answer a questionnaire. In total, 50 chandlers from a wide range of areas were contacted.

The questionnaire was designed to determine:

1. the brands of antifouling paint sold;
2. the proportion of each antifouling product sold;
3. average volumes of antifouling paint sold by chandlers in the UK;
4. when the majority of paint is sold;
5. the sources of the paints.

Biocide concentrations and leaching rates may vary according to the paint colour so on colour preferences was also obtained. The data obtained were input into a Microsoft Excel© spreadsheet for analysis.

2.2.4 Boatyards

A list of boatyards was compiled from the Sail and Power Nautical Almanac and boatyards on the list were contacted by telephone and asked to answer a questionnaire. Fifty boatyards were contacted. The questionnaire was designed to determine:

1. the brands used by boatyards;
2. the range of products used;
3. the number of boats antifouled in a year;
4. the sizes of boat painted;
5. the frequency and timing of application;
6. the amount of paint applied and the methods of application.

In addition, boatyards were asked information on colour preferences, the reasons for using individual products and methods of disposal.

2.2.5 Boat owners

Questionnaires were distributed to boat owners through the Royal Yachting Associations' (RYA) magazine 'Cruising News'. In total, approximately 1500 questionnaires were sent out. The questionnaires were designed to determine:

1. the distribution of different boat types and lengths;

2. the relative proportion of boat owners who antifoul their own boats compared to those who use a boatyard;

3. the brands of antifouling paint that are used;

4. the proportions of individual products that are used;

5. the frequency and timing of antifouling; and

6. the amounts of paint used.

Boat owners were also asked for information on the colour of paint used. Their views on the use of different control options to reduce emissions of antifouling biocide to the aquatic environment were also obtained.

2.2.6 Others

In addition to the major survey groups, one shipyard was contacted to obtain information on the types and quantities of antifouling paint used on large vessels. The British Marine Industries Federation was asked for details of the numbers of chandlers and numbers of vessels in the UK, and the RYA was contacted for information on the numbers of marina berths in the UK.

Table 2.1 Outline of approach used for antifouling usage survey. The number of respondents to the survey is given in parentheses

Survey Group	Number of samples	Information source	Survey Medium	Questions asked	Aim
Biocide Manufacturers	3 (2)	Paint Manufacturers	T	• environmental fate and behaviour of biocides • leaching rates	• information to obtain indication of amounts of biocide entering the aquatic environment
Paint Manufacturers	4 (2)	Chandlers, International	T,I	• paints sold in UK • concentration of active ingredients • total amount of paint sold/year • leaching rates • sales information	• usage information • ranking of actives • potential inputs to environment
Chandlers	50 (50)	Sail and Power Nautical Almanac (1998)	T, P, I	• paints sold • total amounts sold • paints recommended • sales patterns	• regional usage information • usage patterns
Harbours/Marinas	50 (50)	Sail and Power Nautical Almanac (1998)	T,P,I	• size distribution of boats • types of boat	• calculation of inputs on regional basis
Boatyards	50 (50)	Sail and Power Nautical Almanac (1998)	T,P,I	• number of boats antifouled • types of boat antifouled • sizes of boats antifouled • types of paint used	• usage patterns relating to boat types
Shipyards	1 (1)		T	• number of vessels antifouled • size of vessels antifouled • types of paint used	•

Survey Group	Number of samples	Information source	Survey Medium	Questions asked	Aim
Boat owners	500 (390)	Royal Yachting Association	P	• size and type of boat • antifouling used • frequency of antifouling • method of antifouling	• usage patterns relating to boat type • calculation of inputs on local scale
Royal Yachting Association	1		T	• Number of boats afloat in the UK • Number of marina berths	• calculation of inputs on a national scale
British Marine Industries Federation	1		T	• Number of chandlers in the UK • Number of boatyards/marinas • Numbers of vessels afloat	• calculation of inputs on a national scale

T = Telephone interview; P = Postal survey; I = Face to face interview

3. SURVEY RESULTS

3.1 Pilot study

Whilst the objective of the pilot study was to generate information in order to design questionnaires, a number of useful pieces of information were obtained. These are briefly summarised below:

Boatyards

- the average boat size is just over 30 ft;
- motor boats account for around 25% of the total numbers of boats and tend to be larger than sailing boats;
- boat hulls are pressure washed when they are taken out of the water then antifouled between February and April. Pressure washing gets rid of a large proportion of the residual antifouling paint;
- residual antifouling paint is removed by scrubbing with sand paper, use of an antifouling stripper or sand-blasting. Sand blasting and antifouling stripper will remove all of the antifouling paint;
- sand-blasted antifouling is collected and disposed of;
- boatyards antifoul vessels using a roller;
- boat owners have limited knowledge about the environmental, health and safety issues concerning the use of antifouling paints;
- the majority of boat owners antifoul their boats themselves;
- when residual antifouling is washed off a boat it goes straight back into the water.

Chandlers

- chandlers sell the majority of their paint to boat owners, boatyards go direct to the manufacturer or use a wholesaler;
- TBT-based paints are probably still used, boat owners obtaining the paint from the commercial sector;
- interviewees were not sure of the role of the Environment Agency;
- boat owners also obtain antifouling paint from their clubs who buy paint in bulk;

Harbourmasters

- one harbourmaster would like to see the Environment Agency being more pro-active and suggested a working party be set up to look at environmental matters in his area;
- he would also like to receive feedback from any Environment Agency monitoring studies;
- there is a need for closer co-operation between different parties;
- other methods of antifouling include: slippy bottom and ultra-sonic methods;
- in America dry-sailing is popular. This involves the use of large hangers where boats are stored. Fork lift trucks are then used to put the boats in the water prior to use. As a consequence boat maintenance costs are substantially reduced and antifouling paint is not used;
- some harbour authorities use chamber separators to collect water from pressure hosing, particulate material collects in a sump and is removed on a daily basis;
- one respondent was keen to set up a recycling centre to deal with old paint tins, fluid waste and engine oil.

3.2 Main survey

3.2.1 Brands

Five main brands of antifouling paint were identified, namely International, Blakes, Jotun, XM Yachting and Awlgrip (Table 3.1). International had the largest share of the market (Figure 3.1) with an average chandler selling approximately 550 litres and an average boatyard using 99 litres of International paint in one year. There were some differences in the paint brands sold by chandlers and those used by boatyards, the main difference being for the Jotun brand where chandlers only sold small quantities whereas boatyards used similar amounts to the Blakes brand.

The majority of paints were sold and used between February and May. The most popular paint colours being red, blue, Dover white and navy.

Table 3.1 Manufacturers contacted in the survey and their products

Manufacturer	Products
International	Micron CSC, Cruiser Superior, Cruiser Premium, Interspeed Extra Strong, Interspeed 2000, Micron Optima
Blakes	Sea Tech, Titan FGA, Tiger Cruising, Hard Racing, Lynx Plus, Broads Freshwater, Pilot
Jotun	Supertropic, Super, Non-Stop, Racing, Aqualine
XM Yachting	C2000, HS3000, P4000
Awlgrip	Awlstar Gold Label

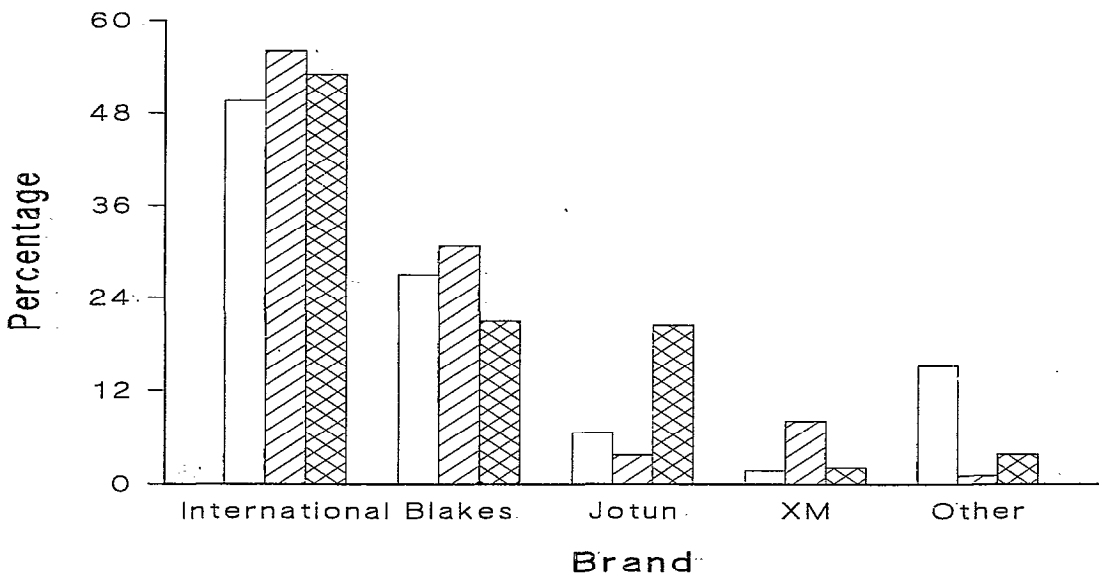

Figure 3.1 Percentage of each antifouling paint brand used by boat owners (open bars), chandlers (hatched bars) and boatyards (cross hatched bars)

3.2.2 Products

Chandlers sold more than 23 types of antifouling paint, whereas the boatyards surveyed used only 18 products (Figure 3.2). The most popular products sold by chandlers were Cruiser Premium (International), Tiger Cruising (Blakes), Micron CSC (International) and Cruiser Superior (International). These products, along with Supertropic (Jotun) were also favoured by boatyards.

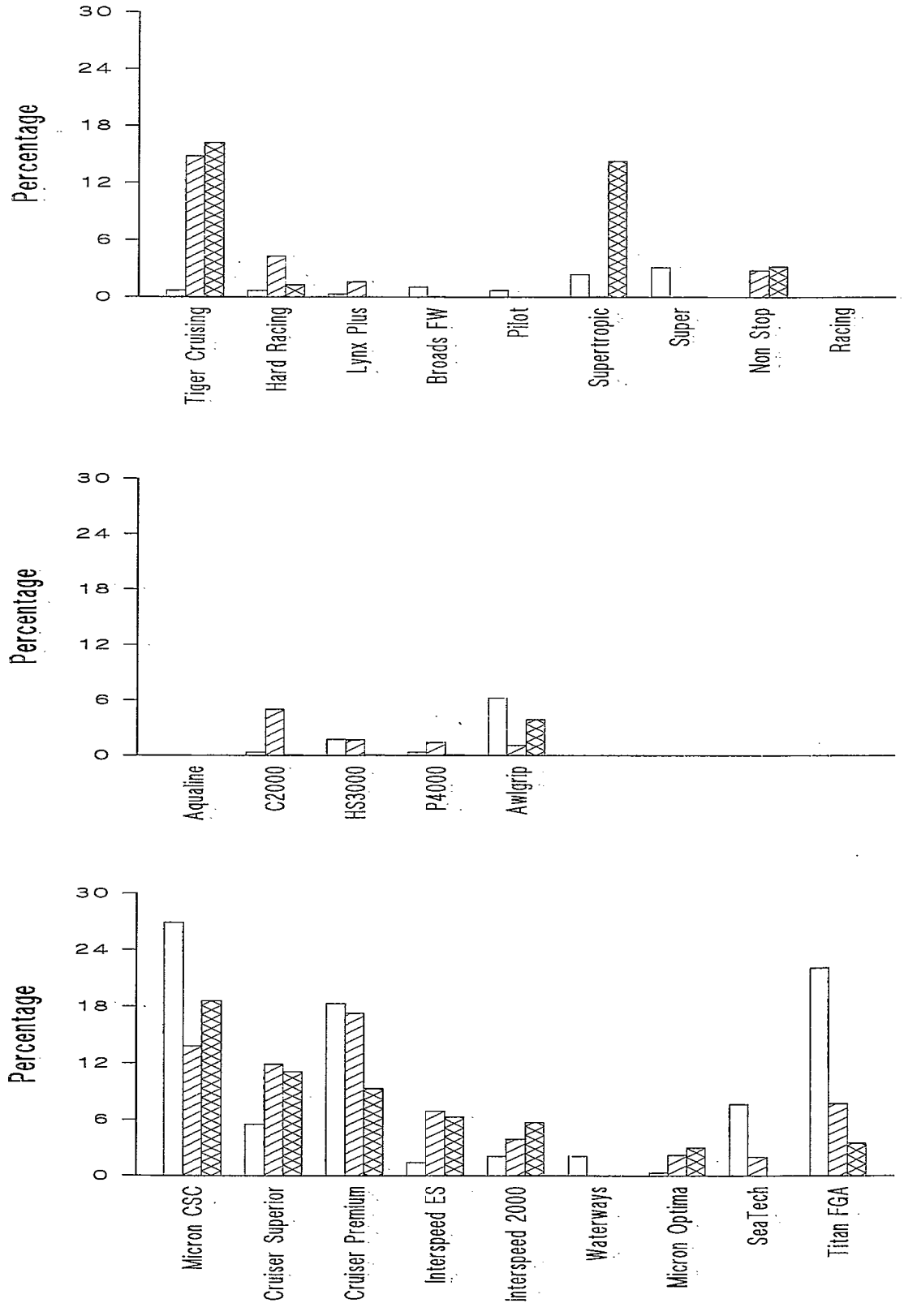

Figure 3.2 Percentage of antifouling products used by boat owners (open bars) and boatyards (cross hatched bars) or sold by chandlers (hatched bars)

3.2.3 Biocides

In order to obtain an indication of which antifouling biocides are likely to be released to the environment, information on the active ingredients contained in each of the products was obtained from Pesticides 1998 (MAFF/HSE, 1998), The Health and Safety Executive and from the manufacturers. The biocides contained in each of the products are detailed in Table 3.2. The most commonly used biocides were copper oxide, copper thiocyanate, diuron, irgarol, zinc pyrithione and dichlofluanid (structures of the organic booster biocides are shown in Figure 3.3). Data on the physicochemical properties, persistence and ecotoxicity of each of the biocides are given in Table 3.3.

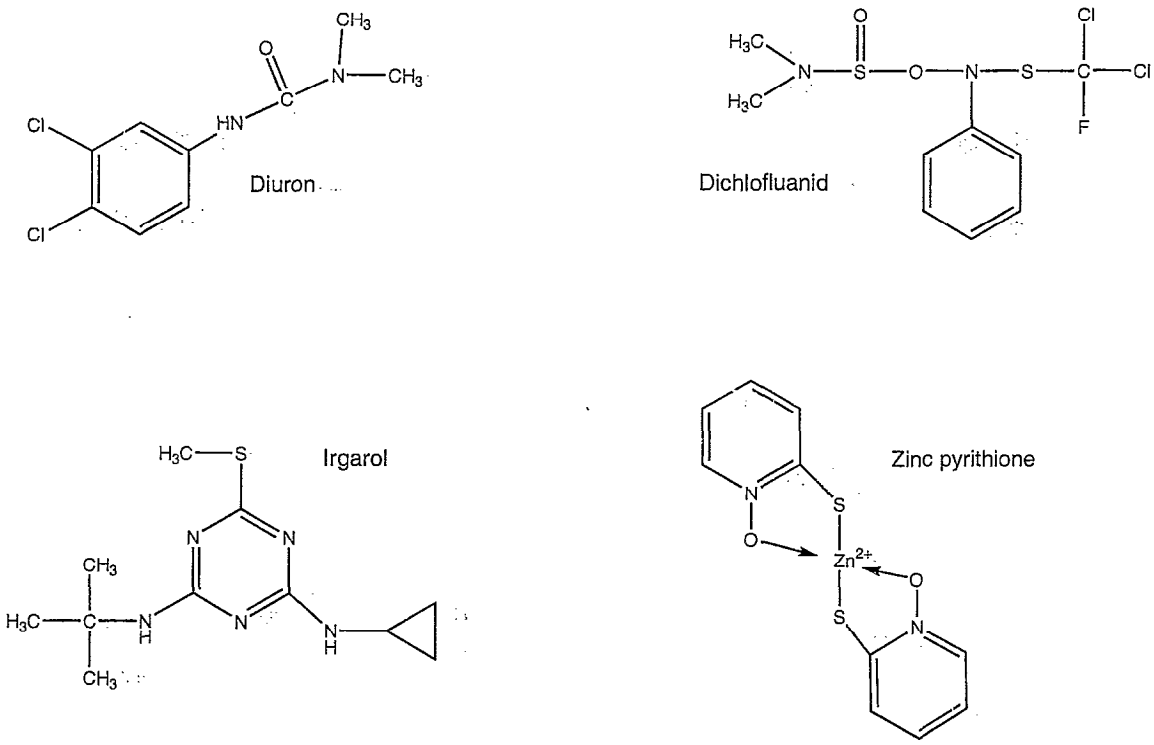

Figure 3.3 Structures of the booster biocides used in antifouling paints applied to leisure craft

Reported concentrations of biocides in each product covered a wide range and for certain products, the biocides used changed with colour. The proportion of each biocide used was determined using the product information provided by boat owners, chandlers and boatyards and median, maximum and minimum concentrations in the paint (Figure 3.4). The results indicated that copper oxide is the predominant biocide followed by diuron, copper thiocyanate, irgarol 1051, zinc pyrithione and dichlofluanid, the other booster biocides that are approved for use by amateur boat owners were not incorporated into any of the products identified.

Table 3.2 Concentrations ranges (% w/w) of biocides in antifouling paint products.

Antifouling Product	Colour	Density	Copper Oxide	Copper Thiocyanate	Diuron	Irgarol 1051	Zinc Pyrithione	Dichlofluanid
Micron CSC		1.6	25-50		2.5-10			
Cruiser Superior		1.35	10-25		2.5-10			
Cruiser Premium		1.6	10-25		1-2.5			
Interspeed Extra Strong		1.5	25-50		1-2.5			
Interspeed 2000		1.3		10-25		0-2.5		
Waterways		1.5	2.5-10					
Micron Optima	red base	2.2	50-100					
	red activator						10-25	
VC System		1.38	50-100					
Prop O Drev TF Black		0.80		5-10		0-50		
Sea Tech		1.7	30-50		2-5			
Titan FGA	red	1.8	20-40					
	grey	1.9	20-40			0.1-5.0		
Tiger Cruising	grey	1.8	20-40			0.1-5.0		
	black	1.9	20-50			0.1-5.0		
	white			15-20		0.1-5.0		
Hard Racing	black	1.7	20-40			0.1-5.0		
	blue	1.7	20-40			0.1-5.0		
Lynx Plus	grey	1.6				0.5-2.0	2-10	
	black	1.6				0.5-2.0	2-10	
Broads Freshwater	blue	1.5	20-50			0.1-5.0		
	green	1.4						
	red		20-30			0.1-5.0		
Pilot		1.5	10-30			0.1-5.0		

Antifouling Product	Colour	Density	Copper Oxide	Copper Thiocyanate	Diuron	Irgarol 1051	Zinc Pyrithione	Dichlofluanid
Hempel (tin free)		1.6*	#			#		
Supertropic		1.6*	21.16					
Super		1.6*	10.1-41.3					
Non-Stop		1.6*	33.0-35.0					1.35-1.53
Racing		1.6*	32-35					
Aqualine		1.6*						
C2000		1.6*	25			1.0		
HS3000		1.6*	30			1.0		
P4000		1.6*	30			1.0		
Awlgrip		1.6*	42.48-46.47					
Marclear		1.6*	#					
VC Offshore		1.6*		#		#		

* - data not available, so mean density of all other products value used.
# - biocide present in product but information on concentrations not available

Table 3.3 Physicochemical properties, persistence and toxicity of antifouling biocides

Biocide	Solubility ($mg\ l^{-1}$)	Kow	Koc	Degradability	Toxicity to fish	Toxicity to algae	Leaching rate ($\mu g\ cm^{-2}\ d^{-1}$)	Reported environmental concentrations	Ref
zinc pyrithione									
irgarol	2.2 - 11.1	631	1240 - 3100	photolysis half life = 273 d; not readily biodegradable	96 h LC50 for Zebra Fish = 400 $\mu g\ l^{-1}$; 96 h LC50 Bluegill sunfish = 2900 $\mu g\ l^{-1}$	72 h EC50 = 1.4 - 2.4 $\mu g\ l^{-1}$	2.5 - 16	4 - 130 $ng\ l^{-1}$	1
diuron	42	631	398	Limited photolysis; non biodegradable	Bluegill 96 h LC50 8.5 - 25 mg/l	96 h EC50 0.04 - 0.12 mg/l		13 - 1000 $ng\ l^{-1}$	2
dichlofluanid	1.3	5000	1100		bluegill sunfish = 0.03 $mg\ l^{-1}$	EC50 = 16 $mg\ l^{-1}$			3
copper(1) oxide	<0.007				10 - 10 200 $\mu g\ l^{-1}$ (Cu^{2+})	1 - 8000 $\mu g\ l^{-1}$ (Cu^{2+})	10 - 20	median of approx. 7 $\mu g\ l^{-1}$ Cu^{2+} for estuaries used by commercial and leisure craft	4
copper(1) thiocyanate	5	0.5			10 - 10 200 $\mu g\ l^{-1}$ (Cu^{2+})	1 - 8000 $\mu g\ l^{-1}$ (Cu^{2+})	10 - 20	median of approx. 7 $\mu g\ l^{-1}$ Cu^{2+} for estuaries used by commercial and leisure craft	4

1 - data provided by Ciba Specialities; 2 - Lewis and Gardiner, 1996; 3 - Tomlin, 1997; 4 - ACP, 1998.
LC50 - 50% lethality concentration; EC50 - 50% effect concentration

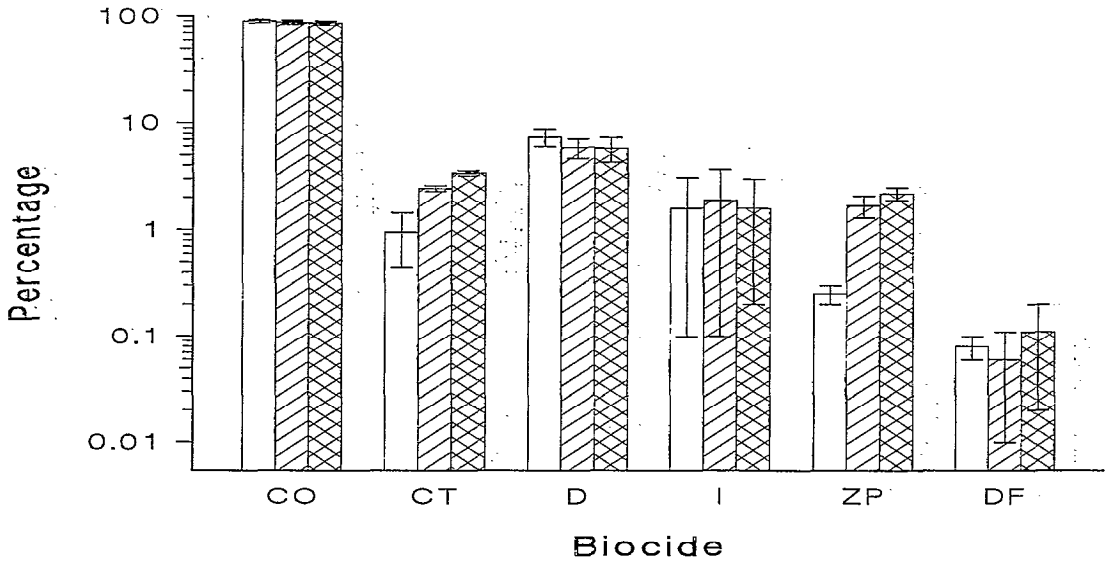

Figure 3.4 Percentage of each biocide used by boat owners (open bars), boatyards (cross-hatched bars) or sold by chandlers (hatched bars). CO = cuprous oxide; CT = copper thiocyanate; D = diuron; I = irgarol 1051; ZP = zinc pyrithione; DF = dichlofluanid. Bars represent the maximum and minimum percentages of each biocide that could be used.

3.2.4 Level of fouling

The extent of fouling varies around the UK. Information on fouling in different areas could therefore be useful in order to control the use of antifouling biocides, e.g. weaker formulations could be used in low fouling areas.

The survey demonstrated that the majority of harbours and marinas were in medium fouling areas (Figure 3.5) with fewer than 20% of the respondents considering their area to be a 'high fouling' area. The results are highly qualitative and are based on the interviewees' perception of fouling.

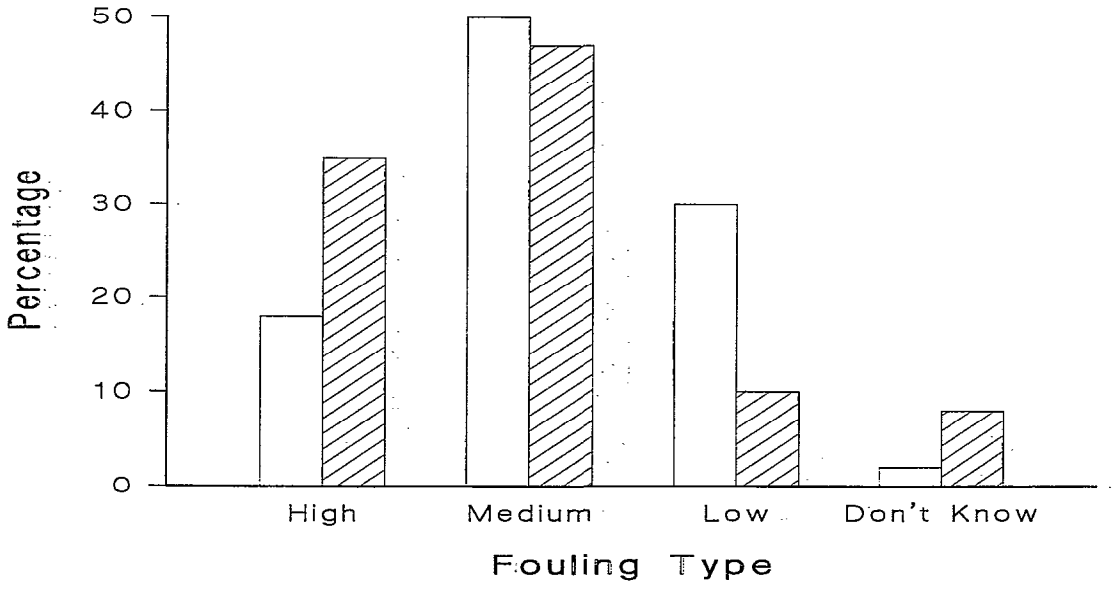

Figure 3.5 Proportion of harbours/marinas (open bars) or individual boats (hatched bars) in either high, medium or low fouling areas.

3.2.5 Boat size and quantities of paint used

The mean boat length in UK harbours was 30.5 ft and 47% were motor boats and 53 % were sailing yachts. The average number of boats kept in a UK marina was 213 (ranging from 30 - 500), the size distribution of boats in a UK marina is illustrated in Figure 3.6.

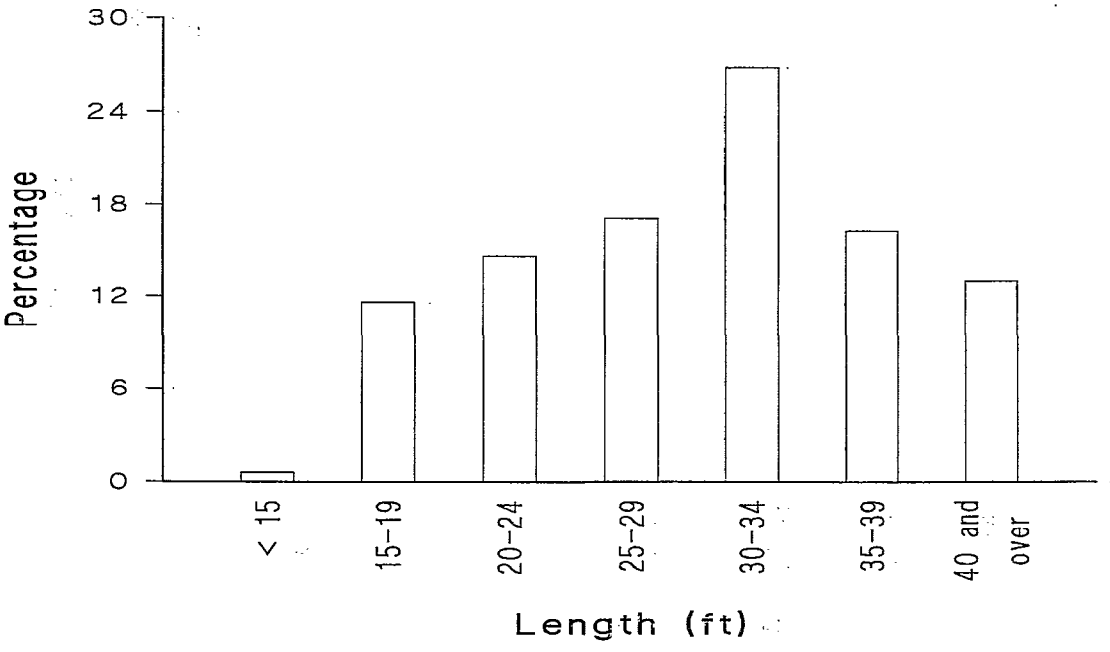

Figure 3.6 Size distribution of boats (not including ships) in UK coastal waters.

Due to their larger hull surface area, motorboats required more paint than sailing yachts (Table 3.4) and the quantities of paint used by boatyards increased with increasing boat length. The quantities used by boatyards were lower than those recommended by Blakes (Blakes, 1998). For boat owners the correlation between boat length and quantity of paint used was weak (Figure 3.7).

Table 3.4 Quantities (L) of antifouling paints used by boatyards for different sized motorboats and yachts. Recommendations made by Blakes for antifouling are also given

Boat size (ft)	Sailing yacht	Blakes recommendation	Motorboat	Blakes recommendation
15 - 20	1.75	-	2.27	-
20 - 25	2.5	2.7	2.76	3.25
25 - 30	3.63	5.2	4.33	4.9
30 - 40	5.54	7.6	6.22	9.13
40 - 50	7.59	12.2	9.0	14.1
>50	16.1	-	12.3	17.5

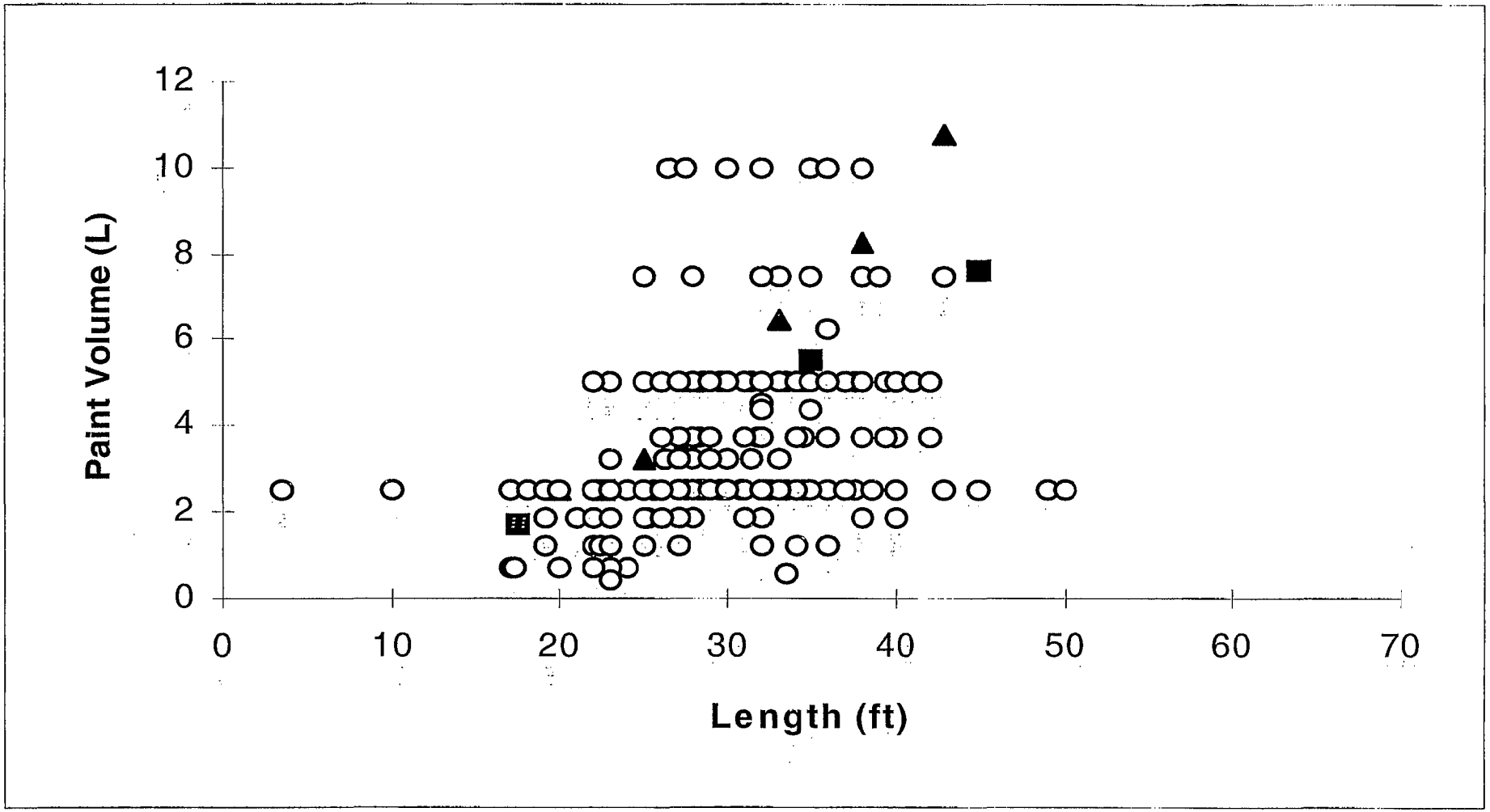

Figure 3.7 **Relationship between boat length and volume of antifouling paint used. Amounts used by boat owners are represented by an open circle, recommended volumes (by Blakes) for different boat sizes are represented by a solid triangle, average amounts used by boatyards are represented by solid squares.**

3.2.6 Paint application and disposal

The majority of boats (85%) were antifouled once a year, with 7.5% being antifouled every two years and 6.5% every three years. Most boat owners (86%) antifouled their boats themselves. Generally vessels were prepared for antifouling using pressure hoses and the new paint was then applied over the existing paint. The majority of boat owners did, however, remove all of the excess paint every five years (Figure 3.8).

The majority of vessels were antifouled ashore (Figure 3.9) although a significant proportion (10.7%) are antifouled either on scrubbing piles, or on the beach. Most boatyards (65%) generally disposed of scrapings/washings in waste bins, skips or controlled areas. A significant proportion (19.2%) of boatyards washed away the scrapings to the river or the sea (Figure 3.10).

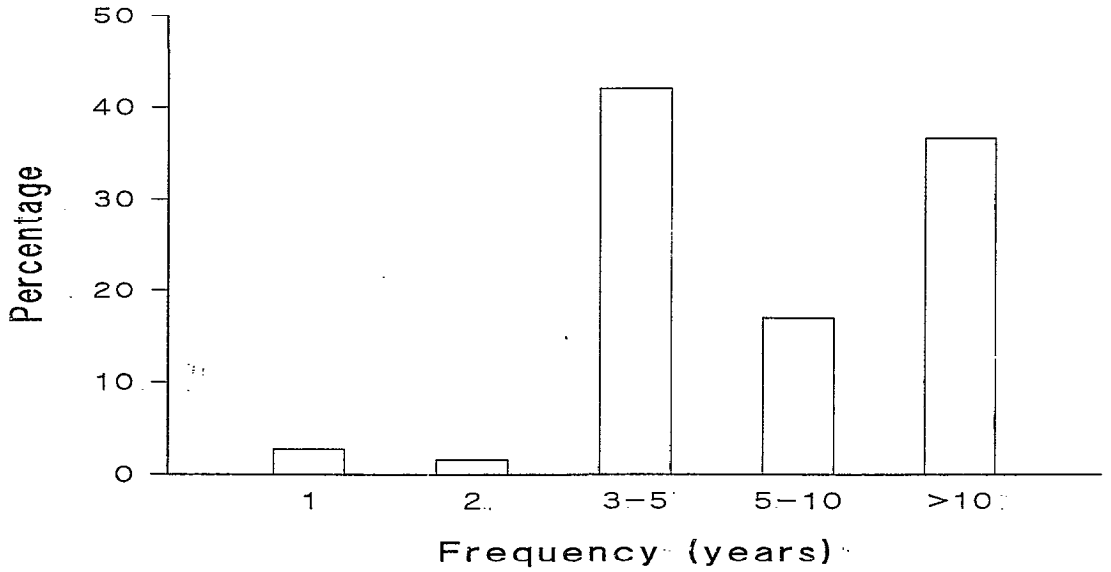

Figure 3.8 Frequency of removal of all residual antifouling paint

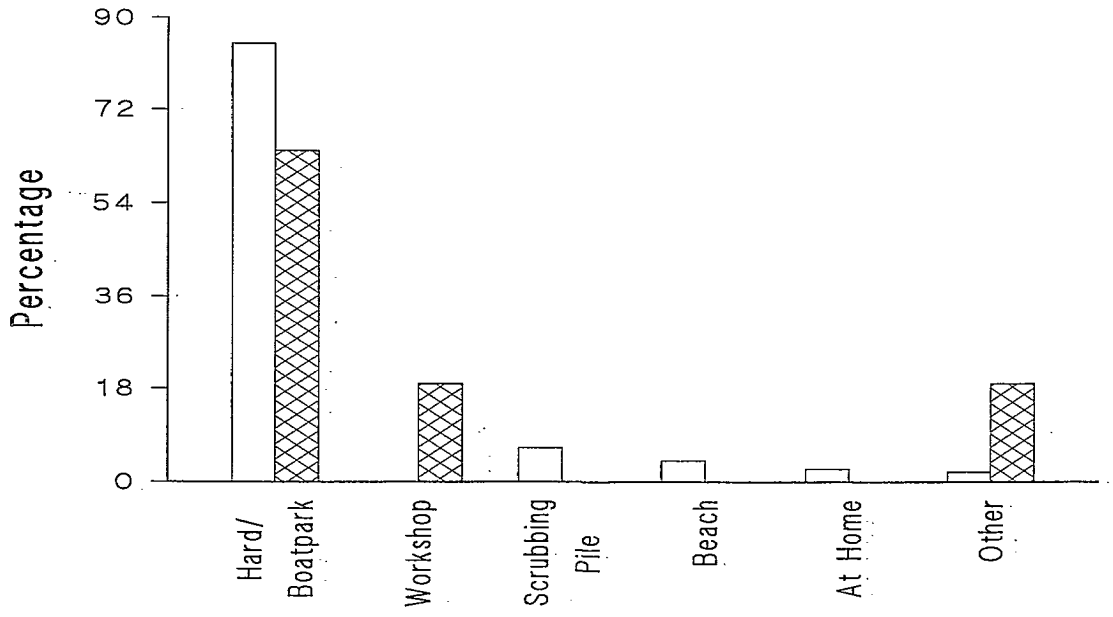

Figure 3.9 Proportion of boats painted at each type of application site by either boat owners (open bars) or boatyards (cross-hatched bars).

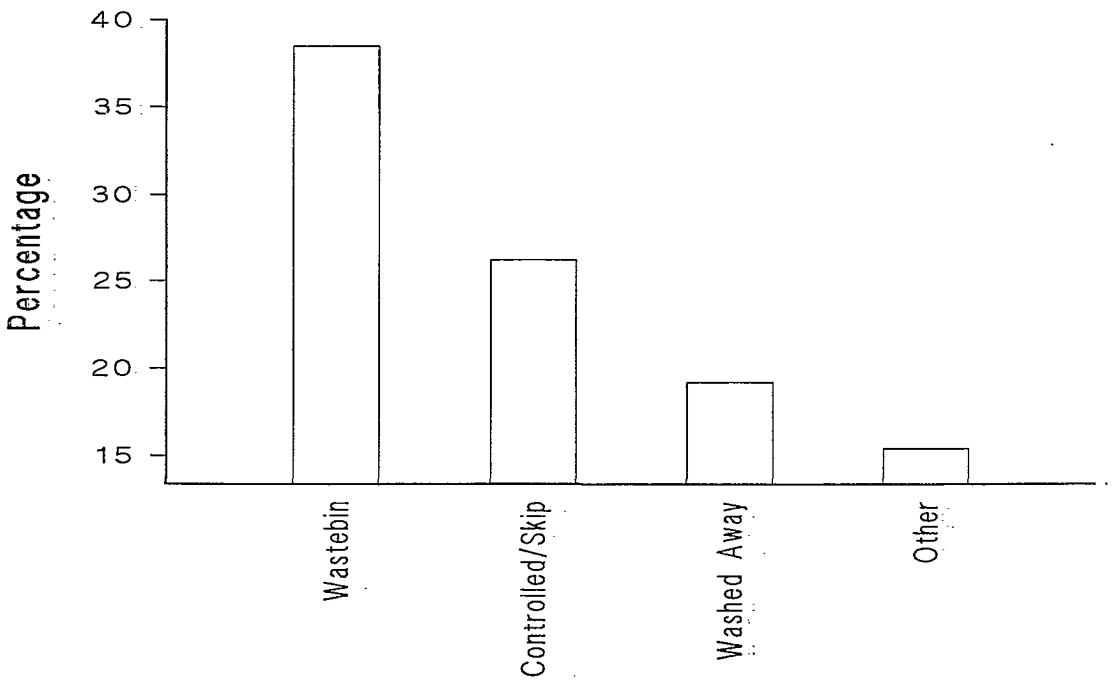

Figure 3.10 Methods of disposal used by boatyards

3.3 Control Options

If scrubbing piles with a catchpit were provided, 43% of boat owners would be willing to use them. Half of the boat owners would be willing to use a yard with facilities to minimise releases of antifouling paints to the environment. If appropriate facilities were provided (e.g. disposal bins and brushes), 75% of boat owners would be willing to dispose of any waste scrapings produced (Figure 3.11).

Boat owners highlighted a number of additional factors that would influence their use of the types of facilities described above and these included: availability, convenience, ease of use, and location (Figure 3.12).

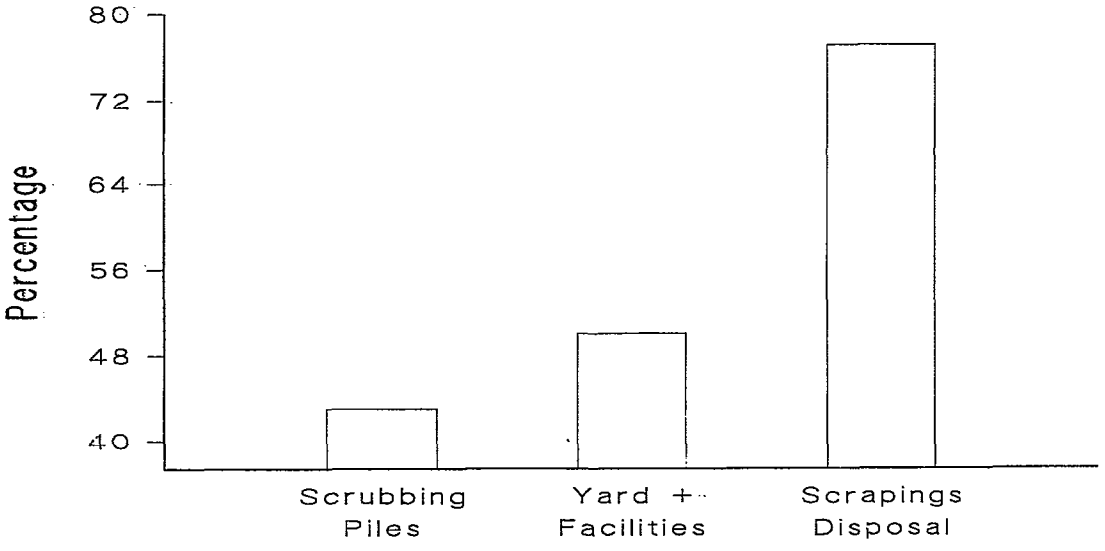

Figure 3.11 Percentages of boat owners who would be willing to use the control options outlined in the questionnaire

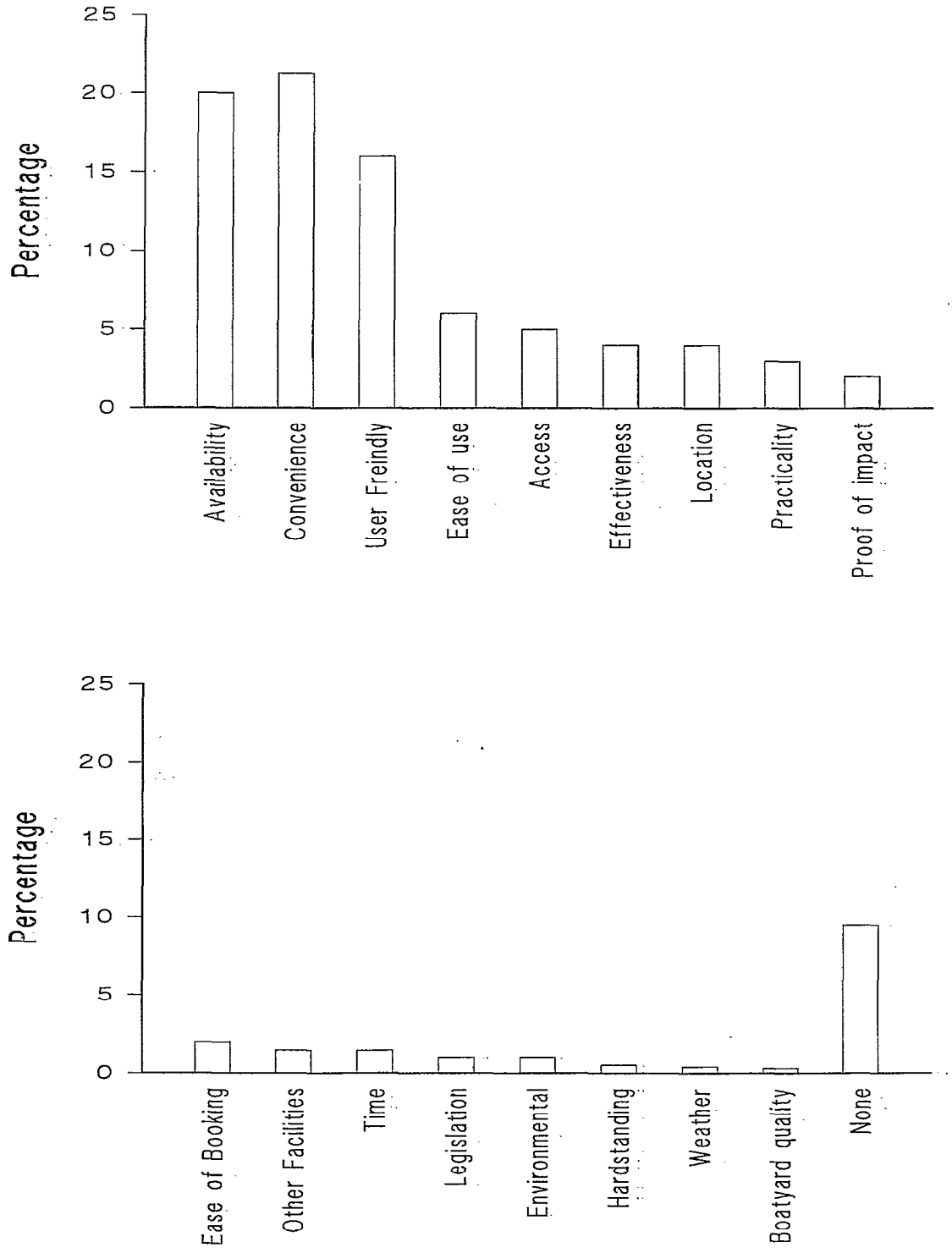

Figure 3.12 Factors that would influence the use of control options by boat owners. Figures are expressed as percentages of the total number of boat owners questioned

4. CALCULATION OF BIOCIDE USAGE/INPUTS

Using the results of the survey, there are a number of approaches that can be used to estimate quantities of antifouling biocides used on UK leisure craft, these include:

1. estimations based on the number of leisure craft afloat in UK waters; and

2. estimations based on antifouling sales from UK chandleries and boatyards.

Whilst estimations can be made of the actual usage of biocides in the UK, estimates of inputs to UK waters is more problematic. The reason for this is that the quantities of each biocide entering the environment are not only dependent on the usage patterns of individual antifouling products but also on other factors such as spillages during paint application, leaching whilst a boat is in the water and the methods used for removal of the antifouling paint (and the frequencies of application/removal). A simple mathematical model is available however for estimating inputs of antifouling biocides to a generic marina (Linders and Luttick, 1995). This model was therefore used in the present study to obtain estimates of possible 'worst case' concentrations for each of the biocides.

4.1 Estimates of biocide usage in the UK

4.1.1 Based on number of boats in UK waters

The British Marine Industries Federation (BMIF) estimate that there are 1.84 million main craft in the UK. This number includes small craft (such as sailing dinghies) that will be kept ashore and which will not be antifouled. An estimate of the number of leisure craft afloat in coastal waters has previously been obtained using aerial photographs; this was found to be 150 000 (Waldock *et al.*, 1995).

An estimate of the number of vessels that are antifouled in the UK coastal waters was also obtained from the total number of coastal marina berths in the UK and the ratio of boats moored in marinas to boats moored elsewhere. The total number of coastal marina berths in the UK is greater than 34 530 (RYA, 1998). The boat owners survey indicated that 47.5% of boat owners kept their boats in marina berths. Consequently the total number of leisure craft moored in UK coastal water was estimated to be greater than 72 766.

The number of leisure craft that are kept in UK coastal waters and that are antifouled was therefore assumed to be between 72 766 and 150 000.

The majority of boat owners (86%) antifouled their boats themselves and the mean amount of antifouling paint used by boat owners was 3.37 litres. The range of amounts of each biocide used in one year by owners of leisure craft in UK coastal water was therefore estimated using Equation 1.

$$B_{Boatowners} = (\sum_{i=1}^{n} B_{Pa\,int\,i} * f) * N * 3.37 \qquad \textbf{Equation 1}$$

Where: $B_{boatowners}$ is the total amount of biocide used by UK boat owners, B_{paint} is the concentration of biocide in each paint product (kg l^{-1}), f is the fraction of the product used with respect to total products used by boat owners (the results of these calculations are expressed as kg biocide l^{-1} of paint used in Appendix B), and N is the number of leisure craft antifouled by boat owners in UK coastal waters (i.e. 62 579 - 129 000 (86% of 72 766 and 150 000 respectively).

Whilst the majority of boat owners antifoul their own vessels, 14% employ boatyards to apply the antifouling paint. The amount of biocide applied by boatyards was therefore calculated using Equation 2.

$$B_{Boatyards} = (\sum_{i=1}^{n} B_{Paint\,i} * f) * N * V \qquad \textbf{Equation 2}$$

Where $B_{Boatyards}$ is the amount of biocide used by UK boatyards, N is the number of vessels treated by boatyards (10 187 or 21 000 (which is 14% of 72 766 and 150 000 respectively) and V is the volume of paint used (5.1 litres for motorboats and 4.45 litres for yachts).

The total amounts of biocide used in the UK was then estimated using Equation 3.

$$B_{Total} = B_{Boatowner} + B_{Boatyard} \qquad \textbf{Equation 3}$$

The results of the calculations based on maximum and minimum boat numbers and maximum and minimum biocide concentrations are given in Appendix B.

4.1.2 Based on number of chandlers

There are 168 chandlers who are members of the British Marine Industries Federation (BMIF) and the BMIF estimate that BMIF members account for between 70 and 75% of the UK marine industry. Assuming that 72.5% of chandlers are members of the BMIF, the total number of chandlers in the UK can be estimated to be 232. As an average chandler sells 980.6 litres of antifouling paint in a year, the amount of each biocide sold can be calculated using Equation 4:

$$B_{Chandler} = (\sum_{i=1}^{n} B_{pa\,int\,i} * f) * 232 * 980.6 \qquad \textbf{Equation 4}$$

Assuming that boatyards do not purchase antifouling paint from chandlers (the survey indicated that the majority of boatyards purchased paint either directly from the manufacturer or from a wholesaler), an estimate of the total amount of biocide used in the UK can be obtained using Equation 5.

$$B_{Total} = B_{Chandler} + B_{Boatyard} \qquad \textbf{Equation 5}$$

4.1.3 Results of usage calculations

Using both approaches described above, copper oxide was found to be used in the highest quantities followed by diuron, irgarol 1051 and copper thiocyanate, zinc pyrithione and dichlofluanid (Table 4.1). There were large differences between the maximum and minimum usage estimates the reason for this being the large differences in biocide concentrations quoted for the individual paint products (see Table 3.2).

Table 4.1 Quantities of antifouling biocides distributed/used in the UK in 1 year

	Maximum Amount (kg yr^{-1})	Minimum Amount (kg yr^{-1})
copper(1)oxide	311769	75173
copper thiocyanate	4216	282
diuron	24738	3288
irgarol 1051	10186	59
zinc pyrithione	8246	1369
dichlofluanid	388	153

4.2 Inputs to the environment

The inputs of each biocide to the aquatic environment will be dependent on the method and location of paint application, the leaching behaviour of the biocide once a painted boat is in the water and the method in which residual antifouling paint is removed from the hull of a boat.

4.2.1 Inputs from pressure hosing

In the Netherlands, emissions of copper during water blasting have been estimated to be between 90 - 2800 mg per leisure vessel (CUWVO, 1991). Based on the estimated number of coastal leisure craft moored in UK water (72 766 and 150 000), and the fraction of boats that use copper-based antifouling (i.e. 0.99 - 1.00), the total amount of copper entering the aquatic environment through water blasting is estimated to be between 6.4 and 420 kg.

4.2.2 Inputs through leaching

Estimates of inputs to the aquatic environment from leaching can be obtained if information is available on the leaching rate of a biocide. For copper, leaching rates are estimated to be between 10 and 20 $\mu g\ cm^{-2}\ d^{-1}$ (100 000 and 200 000 $\mu g\ m^{-2}\ d^{-1}$) (ACP, 1998). Assuming that an average leisure craft has a surface area below the waterline of 10 m^2, the total amount of copper leaching from a boat in a day is estimated to be 1 000 000 - 2 000 000 μg, i.e. 1 - 2 g. There are between 72 766 and 150 000 boats that are antifouled in UK coastal waters, therefore the total amount of copper leaching into UK waters from leisure craft in one day is

estimated to be 72 766 - 300 000 g. Therefore in one year the amount of copper leaching into the environment is 26 560 - 109 502 kg. As the fraction of boats painted with copper-based antifouling is 0.99 - 1.00, the amount of copper entering UK waters through leaching can therefore be estimated to be between 26 294 and 109 502 kg yr^{-1}.

Similar calculations can be performed for irgarol 1051. On the basis that between 27 and 32% of vessels are painted with antifouling containing irgarol and a reported leaching rate of 25 000 - 160 000 $\mu g\ m^{-2}\ d^{-1}$ (Ciba Specialities, personal communication) the amount of irgarol 1051 entering the aquatic environment through leaching can be estimated to be between 1793 and 28 031 kg yr^{-1}.

4.2.3 Inputs to a model marina

The determination of inputs and concentrations of antifouling biocides on a local scale (e.g. into an estuary or into a marina) is more problematic as this will be dependent on the number of boats in a particular area. However, one approach is available for predicting concentrations of antifouling biocides in a model marina (Linders and Luttik, 1995). This model can be used to predict the average concentrations of biocides in a marina containing 250 boats and having the characteristics described in Table 4.2.

Table 4.2 Input parameters used for determining the fate of an antifouling biocide in a model marina (Linders and Luttik, 1995)

Input	Value	Default/Required
Number of yachts in marina	250	D
Mean ship deck area (m^2)	10	D
Water/ship ratio in yacht basin	3	D
Fraction of ships in water	0.5	D
Volume of paint used per yacht (m^3)	0.002	R/D
Cover of antifouling paint ($m^2.m^{-3}$)	2500	R/D
Depth of yacht basin (m)	2.5	D
Fraction of ships in yacht basin	0.71	D
Mean flux of compound ($kg\ m^{-2}\ s^{-1}$)	4.63E-10	R/D
DT50 for advection in the yacht basin (s^{-1})	4.32E+6	D
Fraction of organic carbon in suspended matter ($kg\ kg^{-1}$)	0.1	D
Octanol/water partition coefficient		R
Concentration suspended matter in water ($kg\ m^{-3}$)	0.015	D
First order degradation rate (s^{-1})		R/D

The marina model along with information on usage patterns obtained in the survey was used to predict concentrations of each of the booster biocides. The calculations used are described in Appendix D. Concentrations of biocides ranged from 23 ng l^{-1} (dichlofluanid) to 254 $\mu g\ l^{-1}$ (copper oxide) (Table 4.3).

Table 4.3 Predicted biocide concentrations in a model marina

	Leaching rate ($\mu g\ cm^{-2}\ d^{-1}$)	Percentage of boats treated with biocide	Predicted concentration ($\mu g\ l^{-1}$)
copper(1)oxide	10 - 20	0.99 - 1.00	127 - 254
diuron	default	45 - 52	8.65 - 9.9
irgarol 1051	2.5 - 16	27 - 32	5.43 - 41.2
zinc pyrithione	default	0.6 - 3.8	0.07 - 0.45
dichlofluanid	default	2.1 - 3.2	0.023 - 0.034

5. DISCUSSION AND FUTURE WORK

Fouling is the successive build up of biological growth on underwater surfaces. It is a process that adversely affects the speed of vessels resulting in a decrease in performance. Fouling therefore has negative economic consequences. Antifouling paints are applied to the hulls of ships and boats to reduce or eliminate fouling by releasing biocides which are toxic to the fouling organisms.

In the past, antifouling paints contained organotins and copper compounds as biocides. However, whilst copper is still in use, organotins are not approved for use on vessels under 25 m in length. Certain fouling organisms are resistant to copper and consequently copper has now been supplemented by additional biocides which are known as booster biocides.

Antifouling biocides can enter the environment through leaching or during the paint application and stripping process. As they are by their very nature toxic to aquatic organisms, there is a potential for antifouling biocides to have an impact on non-target organisms. The environmental problems associated with the use of organotin biocides are well documented, however limited data are available for the more recent booster biocides. The Environment Agency therefore commissioned WRc to perform a survey to assess the environmental problems arising from antifouling agents other than organotins.

The specific aims of the survey were to 1) identify the nature of the problem based on usage data; 2) rank the booster biocides in order to target monitoring in the environment and future method development; and 3) provide the Environment Agency with information relating to the use and quantities of antifouling biocides in UK waters.

The project involved an initial pilot study where staff at selected chandlers, boatyards and harbour authorities were interviewed. On the basis of these interviews a number of questionnaires were compiled and used to survey chandlers, marina and harbour operators, boatyards and boat owners. Information on the nature of antifouling products was also obtained from a number of paint manufacturers.

Five main brands of antifouling paint were identified, namely International, Blakes, Jotun, XM Yachting and Awlgrip and a total of 23 products. The biocides used in these products were copper(1)oxide, copper thiocyanate, diuron, irgarol 1051, zinc pyrithione and dichlofluanid. Based on median biocide concentrations, the rank order of biocide in terms of amount used in antifouling products in the UK was copper oxide > diuron > copper thiocyanate approximately equal to irgarol 1051 > zinc pyrithione > dichlofluanid. The total amount of copper used in the UK in 1 year on UK coastal leisure craft was estimated at 75 173 - 311 769 kg. Previous estimates provided by the British Coatings Federation (ACP, 1995) were 130 000 kg.

Whilst a biocide may be used in large quantities, this does not necessarily mean that it will be the predominant biocide in the environment. The reason for this being that the environmental concentrations are primarily dependent on the amounts of biocide emitted to the environment during paint application and removal and through leaching. The main method of paint removal was water-blasting and data were available on likely emissions of copper during the water-blasting process. Using these data along with an estimate of the number of leisure craft in UK

coastal waters, it was estimated that between 6.4 and 420 kg of copper will enter the environment in one year as a result of paint removal. This quantity is significantly less than estimated emissions through leaching (i.e. 26 294 and 109 502 kg yr^{-1}).

Whilst no information was available on the leaching rates of diuron, zinc pyrithione and dichlofluanid, data were available for irgarol 1051. Using these data it was estimated that between 1793 and 28 031 kg of irgarol 1051 leaches into the environment in one year. The upper value is greater than the estimates of the actual amount of irgarol 1051 used in antifouling paints in one year. The likely reason for this is the large range of leaching rates that are reported for irgarol 1051 (i.e. 2.5 - 16 $\mu g\ cm^{-2}\ d^{-1}$).

Likely concentrations of each of the biocides in a marina were also estimated using the modelling approach developed by Linders and Luttik (1995). Using the default values recommended in the model along with data from the survey on the proportion of boats treated with each biocide, concentration ranges of 127 - 254 $\mu g\ l^{-1}$ for copper, 8.65 - 9.9 $\mu g\ l^{-1}$ for diuron, 5.43 - 41.2 $\mu g\ l^{-1}$ for irgarol, 70 - 449 ng l^{-1} for zinc pyrithione and 23 - 34 ng l^{-1} for dichlofluanid were obtained. In general these are more than an order of magnitude higher than the toxicity values reported in Table 3.3. However, the estimated irgarol 1051, diuron and copper concentrations were generally higher than levels measured previously in the marine environment (Lord *et al.*, 1997; Lewis and Gardiner, 1995; ACP, 1995), the predictions of concentrations in marina waters were therefore probably an overestimate.

The marina model that was used in the study does have a number of limitations, for example it assumes that the mean deck surface area is 10 m^2 (the actual value is probably higher than this). A study is, however, currently being performed by WRc for the Health and Safety Executive and the Environment Agency which aims to develop an improved model for predicting concentrations of antifouling biocides in the environment. This model will not only predict concentrations in UK marinas but will also predict concentrations in estuarine waters and sediments.

The survey, also identified the times, frequencies and locations for antifouling application and removal. The majority of boats were treated ashore, although a large number (>10%) were treated either on scrubbing piles or on the beach. Most vessels were painted between February and April and were pressure-washed when they were removed from the water at the end of the season. The majority of boatyards disposed of antifouling waste in a controlled manner (i.e. to skip or to controlled areas) whilst the survey suggested that boat owners left waste paint to be washed into the receiving water. However, the majority of boat owners were willing to use control options if they were provided.

The study was aimed at quantifying the usage of antifouling biocides used by leisure craft in UK coastal waters. Consequently information was not available on the quantities used on large ships and vessels kept in freshwater environments. The quantification of biocide usage by large ships in UK coastal waters is problematic as ships entering UK waters may well have been antifouled in other parts of the world. Moreover, discussions with shipyards indicated that the paints are provided to the shipyards by the ship owners and their identity is unknown.

5.1 Recommendations

Using the data obtained in the study in combination with the marina model and data on releases of copper, it appears that the majority of copper will enter the environment through leaching and that only a small proportion will enter aquatic systems during the paint removal process. Estimates of emissions during water blasting are however based on a Dutch study and may not be applicable to the UK situation. Therefore, efforts should be made to further quantify emissions of antifouling biocides during paint application and removal. The results of such a study could then be used along with information on locations and timings of paint application and removal to determine likely inputs (and the time of the inputs) from these processes.

The leaching rates that have been used in the present study to quantify inputs were either default values or they covered a large range (e.g. irgarol 1051 leaching rates range from 2.5 - 16 $\mu g\ cm^{-2}\ d^{-1}$). Using the irgarol leaching rates, the maximum amount of irgarol estimated to leach into UK waters in one year exceeds the maximum amount used in antifouling paint products. Therefore, leaching rates are not only required for diuron, zinc pyrithione and dichlofluanid but more accurate measures of leaching rate are required in order to estimate more precisely inputs of biocide through leaching. This information should be available from a current HSE study looking at methods for determining leaching rates for antifouling biocides. The results of the survey should assist in the prioritisation of products for leaching rate measurements.

Once the HSE/Environment Agency model and the leaching rate determinations have been performed the environmental impact of each of the antifouling biocides should be assessed by comparing predicted and experimentally-derived concentrations in UK waters with available toxicological information. This process will enable the Environment Agency to assess the environmental impact of the biocides in current use and to prioritise monitoring requirements. On the basis of these studies, control options can then be introduced if appropriate. Results from the DETR monitoring study would also be used in the comparison with ecotoxicological information.

A number of options are available for controlling the releases of biocides to the environment, particularly during the paint application or removal processes. The majority of boat owners were willing to use control options. The effects of introducing these control options should therefore be assessed using data reported in this study and previous studies (e.g. what reduction in emissions would be expected). After this stage, if control options are found to be appropriate a pilot study should be initiated to assess the effects of the control options on biocide concentrations in receiving waters. The pilot study could involve the production of a guidance leaflet for boat owners and the introduction of simple control measures in combination with marina operators and harbour authorities. The effects of the initiative could be assessed by comparing monitoring data obtained prior to the introduction of the control methodologies (this would be available from a current study funded by DETR) with monitoring data obtained after the introduction of the control measures. A guidance document has previously been produced by the RYA in conjunction with the Paintmakers Association, the Boatbuilders National Federation and the Department of the Environment. Ideally, the production of such a document would involve representatives from interested parties including the RYA, the BMIF and harbour authorities.

It is clear from the survey results that harbour authorities, marina operators and chandlers are not aware of the role of the Environment Agency. One of the harbourmasters interviewed would also like to work more closely with the regulators so that resources can be more effectively used. Therefore, it may be appropriate for working parties to be set up to consider the environmental issues (not just those relating to antifouling paints) in rivers and estuaries.

REFERENCES

Advisory Committee on Pesticides (1998) 1st review of copper compounds in antifouling products. Presented by the Health and Safety Executive.

Beaumont, A.R. and Budd, M.D. (1984) High mortality of the larvae of the common mussel at low concentrations of tributyltin. *Mar. Pollut. Bull.* **15**(11): 402-405.

Blakes (1998) The Blakes paint manual. Blakes, Southampton, UK.

CUVO werkgroep (1991) Waterverontreinigingproblematek bij het afspuiten van recreatievaartuigen. Coordintiecommissie uitvoering wet verontreiniging opperlakwateren.

International (1998) The complete guide to boat painting. International Paint Ltd, Southampton, UK.

Lewis, S. and Gardiner, J. (1996) Proposed environmental quality standards for diuron, linuron, chlorotoluron and isoproturon in water. NRA R&D Note 439.

Linders, J.B.H.J. and Luttik, R. (1995) Uniform system for the evaluation of substances. V. ESPE risk assessment of pesticides. *Chemosphere* **31**(5), 3237-3248.

Lord, S., Dollenmeier, P. and Balcomb, R. (1997) Environmental monitoring of an organic algaecide, 2-methylthio-4-tert-butylamin-6-cyclopropylamino-s-triazine, (IRGAROL 1051), under high exposure conditions. Ciba Specialities, Basel.

PSD/HSE (1998) Pesticides 1998. The Stationery Office, London.

Royal Yachting Association (1998) RYA marina guide. RYA, Hampshire.

Sail and Power Nautical Almanac

Smith, B.J. (1981) Tributyltin compounds induce male characteristics on female mude snails (*Nassarius obsoletus*). *J. Appl. Toxicol.* **1**: 141-144.

Tomlin, C.D.S. (1997) The pesticide manual; Eleventh Edition. BCPC, Farnham, UK.

Waldock, M.J. (1986) TBT in UK estuaries 1982 - 1986. Evaluation of environmental problems. In: *Proceedings of the Organotin Symposium*, 23 - 25 September 1986, Washington DC.

APPENDIX A QUESTIONS USED IN THE SURVEY

Table A1 Questions used for the boatyard survey

Question	Categories
Approximately how may boats do you antifoul in a year?	Actual Number; or 1 - 50 50 - 100 100 - 200 200 - 400 > 400 None Don't Know/Refused
What type and number of boats do you antifoul on a yearly basis?	Motor boat Yacht Ship Other
What number of boats do you antifoul in the following size brands?	15 - 19 ft 20 - 24 ft 25 - 29 ft 30 - 34 ft 35 - 39 ft 40 ft and over
What percentage of the antifouling paints that you use are eroding and what percentage are hard?	
Which brands do you use?	International Blakes Jotun XM Yachting Other (Please Specify)
For each of the brands you use please say whether you purchase direct from the manufacturer or through a supplier.	
Why do you use these/this particular brand(s)?	Most effective lowest price most popular customer choice other

Question	Categories
On a yearly basis how much (in litres) of each brand do you stock?	
If you use International how much do you use of each of the following products?	Micron CSC Cruiser Superior Cruiser Premium Interspeed Extra Strong Interspeed 2000 Waterways other (please specify)
If you use Blakes, how much do you use of each of the following products?	SeaTech Titan FGA Tiger Cruising Hard Racing Lynx Plus Broads Freshwater Pilot other (please specify)
If you use Jotun, how much do you use of each of the following products?	Supertropic Super NonStop Racing Aqualine other (please specify)
If you use XM yachting, how much do you use of each of the following products?	C2000 HS3000 P4000 other (please specify)
Which 3 colours are the most popular?	black navy grey red blue (Dover) white green other (please specify)

Question	Categories
Please provide estimates of how much antifoulant paint you would use for the following boats.	Yachts: 15 - 19 ft 20 - 24 ft 25 - 29 ft 30 - 34 ft 35 - 39 ft 40 - 50 ft over 50 ft Motorboats: 15 - 19 ft 20 - 24 ft 25 - 29 ft 30 - 34 ft 35 - 39 ft 40 - 50 ft over 50 ft
On average, how often would you recommend replacing the antifouling paint on a boat?	
Where is the antifouling process carried out at your boatyard?	
How is the waste disposed of?	
How many zinc anodes do you use in a year?	Exact amount; or up to 25 25 - 49 50 - 99 100 - 249 250 - 499 more than 500
What sizes of zinc anode do you use and how many of each size do you use in a year?	up to 1 kg 1 - 3 kg 3 - 5 kg 5 - 10 kg greater than 10 kg
What type of fouling area is the area where your boatyard actually is.	High Medium Low

Table A2 Questions used for the chandlers survey

Question	Categories
Do you sell antifouling paint?	
What percentage of the antifouling paints that you sell are eroding and what percentage are hard?	
Which brands of antifouling paints do you sell?	International Blakes Jotun XM Yachting other (please specify)
For each of the brands that you stock, how much do you purchase direct from the manufacturer and how much do you purchase through a supplier?	
Why do you stock these brands?	most effective lowest price most popular customer choice
On a yearly basis, how much do you sell of each brand (in litres)?	
If you stock International, how much do you sell of each of the following products?	Micron CSC Cruiser Superior Cruiser Premium Interspeed Extra Strong Interspeed 2000 Waterways other (please specify)
If you stock Blakes, how much do you sell of each of the following products?	SeaTech Titan FGA Tiger Cruising Hard Racing Lynx Plus Broads Freshwater Pilot other (please specify)

Question	Categories
If you stock Jotun, how much do you sell of each of the following products?	Supertropic Super NonStop Racing Aqualine other (please specify)
If you stock XM Yachting, how much do you sell of each of the following products?	C2000 HS3000 P4000 other (please specify)
What size of tin is the most popular?	750 ml 2.5 l 5 l 10 l other (please specify)
Which 3 colours would you say are the most popular?	black navy grey red blue (Dover) white green other (please specify)
In which 3 months of the year do you sell most of your antifouling paints?	
How many zinc anodes do you sell in a year?	actual amount; or up to 25 25 - 49 50 - 99 100 - 249 250 - 499 more than 500
What sizes of zinc anode do you sell and how many of each size do you sell in a year?	up to 1 kg 1 - 3 kg 3 - 5 kg over 5 kg

Table A3 Questions used for the harbourmaster/marina survey

Questions	Categories
How many boats are in this marina?	
What proportion of different size boats are in the marina?	under 15 ft 15 - 19 ft 20 - 24 ft 25 - 29 ft 30 - 34 ft 35 - 39 ft 40 ft and over
What proportion are motor boats and yachts?	
What type of fouling area would you say this is?	high medium low
What is the maximum number of boats in the marina?	during high season during low season
What is the minimum number of boats in the marina?	during high season during low season
For how long are boats moored in the marina?	
Do you dredge?	
If you dredge, why do you dredge?	
How often do you dredge?	
How deep do you dredge?	
Which is the most popular place for boat owners to remove and apply antifouling paints?	scrubbing piles the beach boat park other (please specify)
Do you fit zinc anodes to you pontoons?	
What size zinc anodes do you fit?	1 - 3 kg 3 - 5 kg

	5 - 10 kg other (please specify)
How often do you replace the zinc anodes?	yearly every 18 months other (please specify)
Is the marina locked?	
Do you fit zinc anodes to your lock gates?	
What size are they?	1 - 3 kg 3 - 5 kg 5 - 10 kg other (please specify)
How often do you replace the zinc anodes?	yearly every 18 months other (please specify)
Question	Categories
When you remove the zinc anodes, what percentage remains?	
How often do you open the gates in high/low season?	
What number of boats go through the lock on an average daily basis during high/low season?	
Do boats in the harbour/marina "dry out"?	
What percentage of boats "dry out" in the marina?	
For how long each day do they "dry out"?	
What is the size of your marina?	

Table A4 Questions used for the boat owners survey

Question	Categories
What type of vessel do you own?	
What is the length of your boat (in ft)?	
In which area is the boat currently kept?	
Where do you keep your boat?	ashore marina pontoon swinging mooring/fore and aft mooring in river or estuary harbour (e.g. quayside, or buoy in harbour)
In what type of fouling area would you say your boat is kept?	high medium low
Does your boat "dry out"?	
For how long each day approximately does your boat dry out?	
If you own a sailing boat what type of keel does it have?	bilge fin long lifting other (please specify)
Who carries out the antifouling on your boat	yourself boatyard marina
What type of antifouling paint is used?	hard eroding
What brand of antifouling paint do you use most often?	International Blakes Jotun XM Yachting other (please specify)

Question	Categories
If you use the International brand most often, which product do you use?	Micron CSC Cruiser Superior Cruiser Premium Interspeed Extra Strong Interspeed 2000 Waterways Micron Optima other (please specify)
If you use Blakes brand most often, which product do you use?	SeaTech Titan FGA Tiger Cruising Hard Racing Lynx Plus Broads Freshwater Pilot other (please specify)
If you use the Jotun brand most often, which product do you use?	Supertropic Super NonStop Racing Aqualine other (please specify)
If you use the XM Yachting brand most often, which product do you use?	C2000 HS3000 P4000 other (please specify)
How often is your boat antifouled?	
How often do you strip off all of the antifouling paint on your boat?	
Where is your boat antifouled?	ashore at the scrubbing pile on the beach other (please specify)

Question	Categories
What size tin of antifoulant paint do you buy?	750 ml 2.5 l 5 l 10 l other (please specify)
How much of the tin is used at one time?	whole tin 1/2 tin 1/4 tin other (please specify)
Do you have zinc anodes fitted to your boat?	
How many zinc anodes are fitted to your boat?	
What sizes of zinc anode are fitted to your boat?	
How often are the zinc anodes replaced on your boat?	yearly every 2 years every 3 years other (please specify)
Would you be willing to use scrubbing piles with a grid and pit to catch any scrapings?	
Would you be willing to use a yard with specialist equipment to minimise releases?	
Would you be willing to collect and dispose of any scrapings arising from the antifouling process - if brushes and disposal bins were provided?	
Some of these control options may cost money. How much would you be willing to pay for such facilities?	
What factors other than cost would influence the use of such facilities on a yearly basis?	

Question	Categories
Have you used alternative antifoulings that don't rely on the use of toxic chemicals?	
In your opinion, do they work?	

APPENDIX B CONCENTRATIONS OF BIOCIDES SOLD

Table B1 Quantities of antifouling biocide (kg) sold per litre of paint

	Copper oxide	Copper thiocyanate	Diuron	Irgarol 1051	Zinc pyrithione	Dichlofluanid
Boat owners						
maximum	0.65	0.007	0.065	0.023	0.0021	0.00051
minimum	0.34	0.0030	0.019	0.00086	0.00076	0.00045
Chandlers						
maximum	0.58	0.018	0.049	0.026	0.0145	0.0007
minimum	0.30	0.009	0.014	0.00018	0.0053	0.0006
Boatyards						
maximum	0.58	0.0024	0.051	0.021	0.017	0.0008
minimum	0.32	0.0012	0.014	0.00074	0.0068	0.0007

Table B2 **Quantities (kg) of antifouling biocides distributed in one year to the UK marine leisure market**

	Copper oxide	Copper thiocyanate	Diuron	Irgarol 1051	Zinc pyrithione	Dichlofluanid
Chandlers						
Maximum	131950	4095	11147	5915	3299	159
Minimum	68250	2047	3185	41	1206	136
Boatyards						
Maximum	29195	121	2567	1057	856	40
Minimum	7688	29	336	18	163	17
Boat owners						
Maximum	282574	3043	22171	9129	7390	348
Minimum	67485	253	2952	156	1434	148
Boatyards + Boat owners						
Maximum	311769	3164	24738	10186	8246	388
Minimum	75173	282	3288	174	1597	165
Chandlers + Boat owners						
Maximum	161145	4216	13714	6972	4155	199
Minimum	75938	2076	3521	59	1369	153

APPENDIX C NUMBERS OF VESSELS IN UK ESTUARIES

Table C1 Numbers of vessels in UK rivers and estuaries included in the survey

Area	Number of vessels
Torbay	1100
Milford Haven	1200
Swansea	12
Bristol	500
North Wales	400
Lancashire	600
North Shields	400
Beaulieu	110
River Crouch	2500
River Hamble	3261
Southwold	180
The Wash	30
Southampton Water	2600

APPENDIX D CALCULATIONS FOR DETERMINING CONCENTRATIONS OF ANTIFOULING BIOCIDES IN A MODEL MARINA

Table D1 Input/output of emissions of antifoulings and default values in USES

Variable	Symbol	Value	Default/ Requested
Inputs			
Number of yachts in basin	N_{Ship}	250	D
Mean ship deck area (m^2)	$DECKAREA_{avg}$	10	D
Water/ship ratio in yacht basin	$R_{w/s}$	3	D
Fraction of ships in water	F_{Ship}	0.5	D
Volume of paint/yacht (m^3)	L_{anti}	0.002	R/D
Cover of antifouling paint m^2/m^3	R_{anti}	2500	R/D
Depth of yacht basin (m)	$Depth_{yb}$	2.5	D
Fraction ships in yacht basin	$F_{s/ns}$	0.71	D
Mean flux of compound ($Kg/m^2/s$)	$FLUX_{anti}$	4.63e-10	R/D
DT50 for advection in yacht basin	$DT50_{advec,yb}$	4.32e6	D
Fraction of organic carbon in yacht basin	FOC_{susp}	0.10	D
Octanol-water partition coefficient	K_{ow}		R
Concentration of suspended matter in water (kg/m^3)	$SUSPCONC_{surf}$	0.015	D
First order degradation rate in water (s^{-1})	$Kdeg_{water}$		R/D
Output			
Equilibrium diss. concentration in yacht basin (kg/m^3)	$Cwater_{pest,equi}$		

Model Calculations

Necessary harbour area per yacht (m^2):

$$AREA_{w/s} = (1 + R_{w/s}) \cdot DECKAREA_{avg} \qquad \textbf{Equation 6}$$

Total water volume (m^3):

$$VOLUME_{water,yb} = N_{ship} \cdot AREA_{w/s} \cdot DEPTH_{yb} \qquad \textbf{Equation 7}$$

Antifouling surface area in the yacht basin (m^2):

$$AREA_{anti} = R_{anti} \cdot L_{anti} \cdot N_{ship} \cdot F_{ship} \cdot F_{s/ns} \qquad \textbf{Equation 8}$$

Average emission per unit of volume of yacht basin water ($Kg/s/m^3$):

$$E_{avg,\,yb} = \frac{AREA_{anti} \times FLUX_{anti}}{VOLUME_{water,\,yb}} \qquad \textbf{Equation 9}$$

First order rate constant for advection in the yacht basin (s^{-1}):

$$K_{advec,\,yb} = \frac{\ln 2}{DT50_{advec,\,yb}} \qquad \textbf{Equation 10}$$

Suspended solids-water partition coefficient (m^3/kg):

$$Kp_{susp} = \frac{0.411 \cdot FOC_{susp} \cdot Kow}{1000} \qquad \textbf{Equation 11}$$

Fraction dissolved of the chemical:

$$Fdiss_{yb} = \frac{1}{1 + Kp_{susp} \cdot SUSPCONC_{surf}} \qquad \textbf{Equation 12}$$

Total first order rate constant:

$$K_{yb} = Kdeg_{water} \cdot Fdiss_{yb} + K_{advec,yb} \qquad \textbf{Equation 13}$$

Equilibrium dissolved concentration in yacht basin (kg/m^3):

$$Cwater_{pest,\,equi} = \frac{E_{avg,\,yb}}{K_{yb}} \cdot Fdiss_{yb} \qquad \textbf{Equation 14}$$

ADDITION TO R&D TECHNICAL REPORT P215 ENVIRONMENTAL PROBLEMS FROM ANTIFOULING AGENTS

Boatowner Comments Obtained During the Survey

(Note: list is as accurate as handwriting has allowed!)

1. A grid with no piles would suit bilge keels, only a grid is suitable for self eroding paint, it does not scrape off.
2. A product other than thinners that could be available in a special facility to clean up brushes, rollers and trays so they can be reused and the resultant effluent collected and treated in a manner similar to that for waste oil.
3. Antifoulant is only given a light sanding each year when the boat is on land. No possibility of entering the water
4. Antifoulant very strictly controlled in Netherlands. Only allowed to clean bottom on hardstanding area with special drainage. No painting or other work in harbour. Recommend strict controls as in Netherlands.
5. After years of unsatisfactory use of Micron we have had Copperbot applied this year.
6. All clubs should make members clear all rubbish from boatyards.
7. All decisions should be made on proper scientific grounds not due to pressure from environment freaks.
8. All work carried out on club hard standing.
9. Anything yachties do is but a drop in the ocean compared to commercial boats.
10. At our club most scrapings, brushes etc are binned - none are allowed to enter the water.
11. At our club we use a high-pressure washer to clean the hulls on washing out, presumably a better tank could be organised to retain the antifoulant particles.
12. At the club I use all that is required is the will of members to collect scrapings.
13. Ban leaching anti-fouling. Develop durable hard non-metallic bottom protection coatings, provide low cost pressure wash facilities to enable boat hulls to be cleaned periodically throughout the season.
14. Before yachtsman will really believe there is a problem TBT must be banned from fishing and larger vessels.
15. Best option is to develop non-toxic coating that works.
16. Boat pulled to the top of bead in cradle, light sandpaper only with very little pollution.
17. Bring commercial vessels into control
18. Brushes and disposal bins exist at the club I use, all that is required is the will of members to collect scrapings.
19. Catchpit should be compulsory in all boatyard pressure washing areas.
20. Cheaper water-based antifoulant paint.
21. Clean off manually by specialist high-pressure water jet on public piles.
22. Collecting paint scrapings seems obvious but other methods, environmentalists don't need evidence to back their claims.
23. Commercial vessels should be controlled in the same way as private boats.
24. Commercial vessels still use real antifoulant. Poor antifoulant is not cost effective in fuel labour and waste. Boatyards do not have any facilities to collect antifoulant waste.
25. Control the materials used on commercial shipping.
26. Cost is the prime consideration.
27. Cost of such facilities should only reflect cost to yard with small % mark-up not to greatly increase profits on the back of environmental issues.
28. Could be problems in providing facilities for many boats at spring fit out time.
29. Develop thixotropic strippers which neutralise the antifoulant toxicity as it is applied - research lottery funded.
30. Do away with scrubbing posts and pressure wash into converting tanks etc.

31. Do something about the ships still using TBT and moored in Lochs.
32. Easy scraping facilities may mean less anti-foul is needed as boat can be scraped.
33. Encourage alternatives, discourage scraping off and trade pressures.
34. England is full of evangelical conservationists who will sway public opinion to force antifouling to become illegal - we can do nothing about it.
35. Environmental damage from scrapings is unproven - the paint does not even stop weed growing!
36. Environmentalists don't need evidence to back their claims.
37. Eroding antifoulant leaves very little residue therefore no scrapings.
38. Facilities would need to be part of inclusive yard charges.
39. Far better to develop alternative products than to continue using dangerous ones
40. Feel absolutely sure only way to get ALL to do this is to include costs in price of antifouling or else get a discount on returning scrapings.
41. Free copper plating! Stop super-tankers etc. as well as yachts.
42. Hard Standing
43. How can a yard provide facilities for 200 boats all scraping down on a wet Easter weekend?
44. I am keen to try alternative methods, but where is the information and independent evidence that it works?
45. I am puzzled by the "head in sand" attitude to commercial shipping, using TDT antifoulants. The TBT deposits from commercial shipping must be massive when compared with those of leisure boating users.
46. I cannot envisage such controls being any use at all. More bureaucracy for no gain.
47. I collect all my scrapings, rags, brushes etc. every time I antifoul. I put it in a black bin liner and it is burnt at my club. Nothing goes into the water and there is no extra cost.
48. I collect scrapings by vacuuming but disposal is to landfill.
49. I feel that eroding antifoulant eliminates a more regular strip off and is therefore self regulating.
50. I find the scrapings of Micron CSC blow away to dust and are not seen. Encourage lay-up facilities to provide smooth hard standing.
51. I have storage on marsh, reached only by high spring tides, but washing down would accelerate erosion already advanced
52. I lay up onto a gravel hardstanding, how can I collect scrapings.
53. I suspect that old antifoulant scrapings are a very minor part of the problem, as probably are yachts, how many yachts equal one VLCC.
54. I trail sail my boat.
55. I would happily use a commercial operator to antifoul, with all safeguards, if a lift were available. Cost £200 inclusive.
56. I would only accept control options when commercial shipping owners cease using tin based or other toxic antifoulant paints.
57. I would rather have an anti-fouling paint which did not need scrapping off.
58. If big ships can use very contra-environment antifoulant there is little incentive to the yachtsman to view their small amounts of less toxic antifoulant with concern.
59. If marinas / boatyards could bring portable equipment to the boat at reasonable cost I would consider.
60. If marinas or boatyards were to offer a really low-priced lift out/in high pressure hose scrub off I would use it 3-4 times per year.
61. If there was a reasonable low cost non toxic antifoulant (at less than £70 per 2.5 litre) I would prefer to use it even if it meant scrubbing off every 2 months.
62. If we are affecting the environment with these products, they should be banned and new products should be developed to take their place.
63. Impose the same rules on commercial ships.
64. In high density shipping areas - yachts and ships to have same rules- 1 ship pollutes as much as 10s of yachts.
65. In my case it's almost not needed so I'd not be unhappy with a ban.
66. Inducement to use such facilities would probably be necessary to ensure general acceptance.
67. Inexpensive underwater scrubbers similar to car wash shops for small craft may then not need antifoulant.
68. Introducing controls on large commercial vessels, which I believe may still use TBT.
69. Is it possible /realistic /valid to compare area of antifoulant of all recreational craft in an area and visiting commercial shipping. Reason being to establish who causes the problems.
70. It is important that the cheaper option is available through clubs.

71. It's all ridiculous while big ships are exempt.
72. Keen to try alternatives, but unsure where to find information and independent evidence it works.
73. Large ships using TBT.
74. Local bylaws and enforcement.
75. Local councils could readily collect and dispose within existing refuse collection systems.
76. Make epoxy bottoms and Copperbot a requirement for boatbuilders.
77. Make people use professionals and not do antifouling themselves.
78. Many yachts at our marina are antifouled by owners shortly before relaunch. Any improvements to antifoulant arrangements must involve primarily the marina operators.
79. Might try pressure washing a couple of times a season; need easy to use grid with washer.
80. Monitoring enforcement of local antifouling with recommendation more widely discriminated amongst local groups.
81. Moored in the river I have no fouling problems, weed etc grown at sea drops off after return to the moorings.
82. More effective environmentally friendly antifoulant.
83. More effort by the manufacturers to produce user friendly products.
84. Most releases are caused by power washing of hull when it comes out of the water. A grid or pit would have to be provided by the yard on their slipway or hardstanding to collect this debris.
85. Must keep the costs down; the less it costs the more it will be used by all.
86. My boat is pressure washed not scrubbed or scraped , this produces liquid. Scraping is not efficient.
87. My scraping is carried out ashore far from the water and on concrete, which is swept. This seems an ideal situation.
88. No control facilities currently available in Med. Waters.
89. No painting in harbour or other work. Recommend strict controls as in the Netherlands. Our boat is an important historic wooden boat , special considerations apply.
90. Non-toxic anti-foulants are required and low friction surface treatments.
91. Normally washed off with high-pressure water. Big problem is shipping laid up in estuaries.
92. One coat of antifoulant is a requirement of the Sigma 33 class association rules.
93. Our hardstanding is earth and sweeping or vacuuming is difficult
94. Out of water over the winter, living 80 miles away means I have to fit tasks in when I can.
95. Paint manufacturers have a vested interest in maintaining sales.
96. Perhaps if it became cheaper to lift the boat from the water we could have the bottom cleaned more often and not use antifouling?
97. Perhaps the paint manufacturers should have a significant input into possible control solutions, after all it is their products that are the source of the poison!
98. Personally I think that TBT antifoulant should be allowed. It was very effective. Weed/algae seem to be increasing at a terrific rate, perhaps the balance has gone too far the other way.
99. Please also encourage large merchant ships /tankers to be environmentally friendly.
100. Pollution would be controlled better if commercial vessels did not use TBT antifoulant
101. Portable systems to put around or under boat on hardstanding.
102. Power washing when boat lifted is easily most effective removal of loose antifoulant method. Run off back into sea worries me. We need designated area collection / filtration system.
103. Produce a product that does not harm environment and make compulsory for all vessels including commercial.
104. Purify sewage before discharge control.
105. Put the boat alongside piles and sweep up as you progress.
106. Questions above only realistic in major/South England yacht centres.
107. Remember many people who own boats are not "rich" and rely on piles/harbour walls to scrub off and antifoul. It has been a long tradition that should not be lost. Commercial craft should have some constraints on materials used and where and how used.
108. RYAs - obtain factual information regarding evidence of environmental effect and publicise it.
109. Same criteria applied to all users of antifoulant, large commercial V/LS exempt from current controls, restrictions must apply to all users, all V/LS.
110. Seems like wrong questions. My boat is simply pressure washed on craning and washed and painted in spring.
111. Sign an agreement when buying antifoulant.
112. Solution to problem must be simple and not dependent on specialist equipment. Grid and pit or bund and soakaway seem only realistic methods.

113. Some means of testing/ monitoring remaining antifoulant would estimate excessive/ over use.
114. Sometimes the boat winters afloat and annual antifouling is missed.
115. Ten plus boats a day or more could be done and the dock moves from marina to marina.
116. The boatyard hardstanding I earth, rock and stone chippings. It would be impossible to collect antifoulant scrapings.
117. The idea of sweeping up scrapings from the usual muddy gravel of hardstanding seems highly impractical.
118. The products are all over-priced.
119. The small amounts used on pleasure craft compared to commercial vessels suggests it is they that should be targeted.
120. The strict controls in Holland are not burdensome - the yards are set-up for it.
121. The Tudor sailing club might acquire specialist equipment if approached for 100 boats.
122. The wind usually makes collection of dust and chipping difficult or impossible.
123. This is all very well but it can amount to nothing until control is exercised other over the use of toxic antifoulants.
124. This is important that the cheaper option is available through clubs.
125. To impose extra costs to DIY sailors could lead to more thoughtless actions. Encourage good practice. Don't charge.
126. Trailable boat, which is brought in each time, should be antifouling prior to each sailing season.
127. Unless international water it's not feasible. There are too many controls already. The control needs to be in the supply of "wrong" materials perhaps.
128. Until commercial shipping stops using toxic antifoulant, recreational use change seems pointless.
129. Until large ships' antifoulant is controlled or changed, I cannot see why small boats should do anything other than what they do at present.
130. Until the use of TBT is banned for all vessels it is illogical even nonsensical to ban its use by pleasure craft. For these reasons its use by pleasure craft is not unknown here.
131. Use magnesium anode - much more effective, does not scale up like zinc.
132. Use of tin-free antifoul for vessels above 24 metres also.
133. Very unlikely that any such facilities available in this area.
134. Waste water and scrapings should be channelled through sieve and carefully disposed of not into sea.
135. We lay up on the beach and float at spring, therefore it is difficult to collect scrapings.
136. We need much cheaper lift and scrub facilities including weekend working and antifoulant could be eliminated. Most would pay £150 per year for 4-5 scrubs rather than antifoulant.
137. We paint our boat on concrete so there does not seem to be any run-off into the sea, although it makes me ill as I am violently allergic to it.
138. We pay enough for antifoulant etc - let the manufacturers provide facilities for recovery of waste, good PR stuff!
139. What we want is a good paint remover that shifts 4-5 coats at one application.
140. When yard hoses hull undersides down at the end of season, water and antifoulant scrapings should be channelled through a sieve and disposed of carefully not directly into the sea.
141. Why bother, the big ships don't, and they use many times the weight of biocide than yachts do.
142. Why not create small dry docks and have 2/3 boats in at a time so 10+ boats a day or more could be done and the dock moves from marina to marina.
143. Would be problems providing facilities for many boats at spring fit out time.
144. Would happily lay a large dustsheet under the boat whilst antifouling if such were provided easily.
145. Would prefer to use a cheap non-stick type of coating.

Correction to Table 4.3, Page 33

Percentage of boats treated with copper should be 99 - 100 and not 0.00 - 1.00