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Disposal of wastes at sea, Part III - The field assessment of effects

by

I. C. White, M. S. Rolfe and P. A. Hardiman

Fisheries Laboratory, Burnham-on-Crouch, Essex

INTRODUCTION

For many years the UK has operated a voluntary scheme for the control of waste disposal from ships (dumping) both inside and outside its territorial waters. Portmann and Wilson (1973) and Rolfe (1973) in Parts I and II of this paper discussed the factors to be considered in assessing the suitability of wastes for disposal and the selection of dumping grounds. With the passing of the Dumping at Sea Act (1974) the voluntary scheme has been replaced by statutory control and the Ministry of Agriculture, Fisheries and Food has assumed responsibility for the operation of this legislation and thus also for the dumping of a wide variety of wastes into numerous disposal grounds around the UK coast. It has therefore become increasingly important to assess the suitability of proposed dumping grounds and to determine the effects of existing disposals on the fisheries and general ecological health of the area. The magnitude and difficulty of the problem will be apparent to ecologists and non-ecologists alike and it is essential that a practical and meaningful approach be adopted. Laboratory assessment is not adequate for the task and only investigations <u>in the field</u> are likely to yield the information needed.

The nature and extent of any particular field investigation depends on the precise area in question, its fisheries, and the wastes it is receiving, but the overall primary aim must be to gain as clear a picture of the condition of the area as possible in the time available. Possibly the most important aspect of any investigation will be a survey of the benthic animals in the area, because these are generally immobile and therefore subject throughout their life to the physical and chemical conditions of the area. Thus, the status of the benthos at a particular time is the result of influences, including those of man, over a relatively long preceding period. The position of benthic organisms near the base of marine food webs also makes their well-being essential to the long term survival of some of the mobile commercial fish species that can avoid transient adverse conditions.

It has long been recognized that benthic communities may be distinguished according to their dominant species (Petersen, 1913). Thus the discovery of particular species in an area may enable the community to be defined without necessitating the recovery and enumeration of all fauna actually present. However, the traditional way of investigating a marine benthic community is to undertake a detailed sampling programme, followed by identification and enumeration of all the constituents of the fauna collected. Such a survey would normally be repeated at frequent intervals, and over a period of time, often many years, changes in the fauna in terms of either abundance or composition might be revealed. Indices such as species diversity, biomass, etc. are frequently used to aid this process. Long-term studies, although necessarily labour-intensive, are undoubtedly essential in order to understand the basic ecology of benthic communities. Nevertheless, even when such studies reveal significant ecological changes, the causes invariably remain obscure and it is rarely possible to distinguish man-induced effects against the background of erratic natural fluctuations which are typical of all animal communities, not least those in the marine environment (Lewis, 1972). Therefore, when a large number of offshore sites need to be investigated on a regular basis, a detailed approach is invariably not practicable, in view of the enormous resources required, and can rarely be justified by the results achieved.

This paper describes the approach being developed by the Fisheries Laboratory at Burnham-on-Crouch for the rapid field assessment of offshore dumping areas, using well-established techniques. Attention is devoted almost entirely to the procedure adopted for the sampling of benthic communities, because this aspect has necessitated the greatest divergence from the traditional approach outlined above. The results of a sampling programme in Liverpool Bay designed to test the validity of such methods are considered.

METHODS

Figure 1 illustrates the basic procedure adopted for a rapid assessment of a dumping ground. Only the benthic aspects will be considered here in any detail.

Before practical work is carried out all available data on the benthos, fisheries, hydrography, sediments and waste-disposal operations must be assembled and used to plan the overall sampling programme. The extent of the tidal ellipse about the discharge site delineates the area where maximum detection of the waste is most likely to occur, and this can therefore be taken initially as the boundary of the survey area. Other available hydrographic data and details of dumping activities are then consulted in order to draw up a grid of sampling stations for grabbing; tentative positions are also fixed for subsequent Agassiz and otter trawl stations. Extra grabbing stations may be added as necessary during the survey, for example if there is evidence of short dumping or if the currents influencing the dispersion and transport of the waste are found not to coincide with available (surface) tidal stream data. The numbers of stations worked depend on the total time and man-power available for on-board analysis; for example, with a 5-man team on a large (approximately 500 tonnes) fully equiped research vessel, something of the order of 40 grabbing stations, covering approximately $400km^2$, can be completed in two working days, with Agassiz and otter trawl stations and any other minor studies occupying a further day.

To date, $1/10\ m^2$ Smith-McIntyre grabs have been used effectively, although in sheltered conditions with little tide the simpler Van Veen grab can be successfully and more rapidly deployed. A series of grab hauls is made at each station until two visually similar samples are obtained. Normally three hauls are sufficient to determine the predominant character of the sediments. A description of the undisturbed surface sediment in each haul is recorded in terms of mud, sand, gravel, etc. present, and particular attention is given to the presence of obvious organic matter and materials possibly derived from dumping, the presence of dead fauna or their shells and any other characteristics, however minor they may appear at the time. Less obvious features are recorded as they come to light during subsequent sieving. A surface sediment sample (top 1 cm) is taken with a flat-edged plastic spoon from one grab haul at each station and deep-frozen to provide material for particle size, organic and chemical analysis at the laboratory.

The choice of mesh size for the sieving of the remainder of the samples in order to recover the fauna depends on the sediment encountered and the man-power available. First, the sample is carefully washed through a 2mm-meshed sieve and, if required, the sievings can be collected and washed through a

1mm- or 0.5mm-meshed sieve. The sievings are placed on white trays and the fauna picked out and identified to genus or species level and recorded. Obviously, the use of a 1mm- or 0.5mm-mesh greatly prolongs this process and very few of the additional fauna are identifiable on sight. Those specimens which cannot be immediately identified are retained for subsequent inspection at the laboratory.

In some conditions, for example in strong tides or on a very hard substrate, effective grabbing is not possible at all stations and an anchor-dredge is used to obtain semi-quantitative samples. Even when a grab sampling programme has been successfully carried out, a series of anchor-dredge hauls is made to collect deep-burrowing animals missed by the grab. This is followed by a number of Agassiz trawl hauls to obtain epifauna and a range of suitable common invertebrates for subsequent chemical analysis. Finally, one or more otter trawl hauls are made in the vicinity of the worked area to obtain further data on the fauna of the area and to collect samples of commercial fish and shellfish for chemical analysis. Fish guts are also examined to assess the importance of resident benthic species as fish food. In areas of rough ground, where even bobbined trawls are unsuitable, fish samples may be taken (with luck!) by rod and line. Normally, this would complete the on-board work, although in some instances additional techniques such as underwater television, echo-sounding and sector-scanning surveys, and infield toxicity tests may be employed.

In the case of the survey carried out in Liverpool Bay to test the validity of this rapid assessment approach, the procedure described above was adopted but with the following amendments:

(1) The extensive background information available from previous investigations (eg: Department of the Environment, 1972) was not referred to, in order to simulate the situation that would arise when working in an area where little previous work had been done.

(2) All the fauna recovered and the sievings were preserved for subsequent detailed examination at the laboratory, in order to establish the efficiency of the on-board picking-out and identification.

RESULTS AND DISCUSSION

Figure 2 illustrates the position of the 40 grab, 10 Agassiz trawl and 2 otter trawl stations worked in October 1973 in the vicinity of the North-West Light Float (NWLF) dumping ground in Liverpool Bay.

(a) Efficiency of recovery and identification of fauna

The total numbers of species recovered by on-board and laboratory analysis are listed in Table 1 and a comparison is made for those recovered by both procedures.

To some extent the efficiency of recovery and identification must be related to the size and conspicuousness of the specimens encountered. For example, 419 Mysella bidentata, a small bivalve mollusc rarely exceeding 5mm in length, were recovered during laboratory re-examination, although none had been found on board. In contrast 63% of the larger bivalve (Cultellus pellucidus) were picked out and readily identified. This relatively high recovery rate was probably due in part to the conspicuous shape of the mollusc and the fact that all specimens recovered on board and in the laboratory exceeded 1 cm. Larger specimens of other molluscs were also clearly visible on board (eg, Venus striatula, Dosinia exoleta, Nucula sp.) but the failure to observe many small spat of these species on board resulted in low overall recovery efficiency.

On board, the larger polychaetes found at most stations were readily recovered and identified to generic, if not to specific, level (eg Nephtys sp., Pectinaria sp., Glycera sp., Owenia fusiformis, Scalibregma inflatum) but the majority of the smaller specimens were grouped together as 'unidentified polychaetes' and, unless any were clearly distinguishable from the others, they were regarded as only one 'species' for the purposes of the on-board assessment. This partly accounts for the increased number of species recovered during laboratory re-examination (Tables 1 and 2).

In general, once picked out on board, most of the echinoderms, molluscs and larger crustaceans were readily identified, but no attempt was made to identify the majority of the amphipods, coelenterates, nemertines, ascidians and other smaller groups (see Table 1). In addition, the laboratory examination revealed a few incorrect identifications, mainly small bivalve molluscs.

Another factor influencing the efficiency of recovery was the nature of the substrate encountered in any sample. For example, the presence of much broken shell at some stations obscured many smaller animals, whereas in the laboratory living and dead material could be readily distinguished with the aid of vital stains such as Eosin or Rose Bengal.

(b) Distribution of species

The distributions of selected species recovered from both on-board and laboratory analysis are illustrated in Figures 3-7. Although the inefficiency of recovery of certain species is reflected in differences in the two resulting distributions, for example *Glycera* sp. (Figures 3a and b), many species show remarkably similar distributions, for example *Owenia fusiformis*, *Scalibregma inflatum*, *Nephtys* sp., *Cultellus pellucidus* (Figures 4-7), even though some of these species show a somewhat increased occurrence after laboratory re-examination. However, both sets of data show a basically similar pattern of distribution, with two main 'communities' being present:

(i) an area to the north and north-west of the North-West Light Float (NWLF), roughly corresponding with an area of gravelly sediments and rich in *Pectinaria* sp., *Owenia fusiformis*, *Cerianthus lloydi* and *Scalibregma inflatum*,

(ii) an area to the south and east dominated by *Cultellus pellucidus* and *Nephtys* sp.

The species diversity indices (Margalef's d) for all fauna at each station from both on-board and laboratory data (Figures 8a and b) indicate increased diversity north of the NWLF. The diversity indices, being influenced by sample size as well as composition, tend to be greater for the laboratory-derived data but, using Spearman's rho for comparing ranked data (Elliott, 1971), they are shown to be statistically similar to the diversity indices derived from the rapid assessment ($r_s = 0.7296$, $P < 0.001$). Similarly, tests using Spearman's rho show that the numbers of species and of individuals at each station derived both from on-board and laboratory analyses, although different in absolute numbers, are statistically similar in their ranked order ($r_s = 0.7145$ and 0.5802, $P < 0.001$).

(c) Effort

The effort involved in arriving at the two sets of results was widely different; a total of 10 man-hours was involved in the on-board picking out and identification, compared with 280 man-hours for the equivalent work in the laboratory (Table 2).

(d) Limitations of the 'rapid' method

The rapid approach is obviously subject to a number of limitations but from our findings useful results can be achieved as long as certain requirements are met. Probably the most important is the availability of sufficient trained man-power, most especially for the rapid and accurate identification of the fauna, in order to ensure that delays do not occur in any part of the on-board process. From our experience five people are required (besides the deckhands who operate the winch): three to handle the grab or other gear and to sieve the samples, and two to sort and identify the fauna and collect the sediment samples. The other major requirement is a sufficiently large vessel to provide a stable platform in all but the most severe weather. It should have adequate laboratory facilities and navigational aids. Other necessary requirements include an adequate assortment of sampling gear in good working order, with replacements for the most vital parts.

Although the development of this rapid assessment approach is a continuing process, two aspects in particular require improvement. Firstly, an increase in the efficiency of sorting and identification would be an obvious advantage. Various techniques such as flotation have been tried, but are generally unsuccessful at sea, and at present no satisfactory alternative to manual sorting has been found. Identification of the fauna, although obviously dependent on the expertise of the individual worker, could be improved by the use of aids such as sets of less readily identifiable but common fauna (for example the various species of Nucula), preserved and mounted in epoxy resin blocks to serve as 'reminders' during identification.

Secondly, although not discussed in this paper, the assessment of sediment types is vital to the understanding of species/sediment relationships and improved recognition of benthic communities, and a more reliable and reproducible on-board technique is required. This might be achieved by comparing fresh sediments with suitably prepared mixtures, although local differences in geological composition might create further difficulties.

CONCLUSIONS

In spite of the limitations it is considered that valuable information on benthos distribution can be gained from the far less labour-intensive rapid analysis on-board ship. This information, together with laboratory-derived data on physical and chemical aspects of the sediment, benthos and fish from the area, allows a practical assessment to be made of the suitability of an area to receive wastes or to determine whether gross changes have resulted from existing dumping operations. The causes of more subtle changes are likely to remain obscure whichever approach is adopted. These general conclusions have been borne out by investigations made in other dumping areas.

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TABLE 1

'SPECIES' RECOVERED FROM ON-BOARD AND LABORATORY EXAMINATION, WITH COMPARISON OF EFFICIENCY OF RECOVERY FOR SPECIES FOUND ON BOTH OCCASIONS

Figures in parentheses indicate data from further identification

Species	Identified thus on board (*)	Identified further in laboratory (*)	Numbers found on board	Numbers found in laboratory	% Recovery on board
PHYLUM COELENTERATA					
Adamsia palliata	*		1	1	
Alcyonium digitatum	*		2	2	
Cerianthus lloydi				161	
Tubularia sp.				5	
Anthozoa - burrowing	*	*	43	(161)	26.7
Anthozoa - others	*		2	92	
Hydroida	*		12	56	21.4
	5		60	317	18.9
PHYLUM ANNELIDA					
Ampharete grubei				1	
Amphicteis gunneri				166	
Eulalia viridis				206	
Goniada maculata				86	
Hydroides norwegica				127	
Jasmineira elegans				64	
Lanice conchilega	*		9	1379	0.7
Marphysa balli				1	
Nematonereis unicornis				8	
Notomastus latericeus				5	
Owenia fusiformis	*		104	178	58.4
Pectinaria auricoma				15	
Pectinaria koreni				1822	
Phyllodoce maculata				37	
Pomatoceros triqueter				47	
Sabella pavonina				9	
Scalibregma inflatum	*		89	229	38.9
Spiophanes bombyx				16	
Aonides sp.				103	
Glycera sp.	*		24	208	11.5
Gyptis sp.				1	
Lumbrinereis sp.				287	
Magelona sp.				106	
Nephtys sp.	*		95	335	28.4
Ophelia sp.				14	
Pectinaria sp.	*	*	1190	(1837)	64.8
Polydora sp.				33	

TABLE 1 (Continued) (2)

Species	Identified thus on board (*)	Identified further in laboratory (*)	Numbers found on board	Numbers found in laboratory	% Recovery on board
Aphroditidae				51	
Chlorhaemidae				26	
Cirratulidae				682	
Eunicidae	*	*	1	9	
Hesionidae				38	
Maldanidae	*		122	759	16.1
Nereidae	*		3	6	
Opheliidae	*	*	4	(14)	28.6
Phyllodocidae	*		4	100	
Polynoinae	*		5	16	31.3
Sabellidae	*	*	5	(9)	55.6
Syllidae				3	
Terrebellidae	*		8	37	21.6
Unidentified polychaetes			420	367	
	14		2083	7577	27.5
PHYLUM ARTHROPODA					
Callianassa subterranea	*		1	1	
Crangon allmani	*		1	1	
Crangon crangon	*		1	1	
Ebalia tuberosa	*		5	16	31.2
Galathea intermedia				6	
Gnathia maxillaris				29	
Hippolyte varians				1	
Macropodia rostrata				5	
Pagurus bernhardus				3	
Pagurus prideauxi				1	
Philocherus bispinosus				2	
Philocherus sculptus				2	
Philocherus trispinosus				2	
Porcellana longicornis				9	
Portunus depurator				13	
Portunus pusillus				3	
Processa edulis				1	
Upogebia deltaura	*		25	208	12.0
Upogebia stellata				1	
Callianassa sp.				3	
Galathea sp.	*	*	5	(6)	83.3
Macropodia sp.	*	*	2	(5)	
Pagurus sp.	*	*	4	1(+ 4)	80.0
Portunus sp.	*	*	8	(16)	50.0

TABLE 1 (Continued) (3)

Species	Identified thus on board (*)	Identified further in laboratory (*)	Numbers found on board	Numbers found in laboratory	% Recovery on board
Caprellidae	*		1	37	
Pycnogonidae	*		1	7	
Natantia	*		2	1	
Reptantia	*		3		
Amphipoda	*		81	1107	7.3
Cumacea	*		3	44	
Euphausidacea				7	
Isopoda	*		1	18	
Cirripedia				1	
	16		144	1531	9.4
PHYLUM MOLLUSCA					
Abra alba	*		40	86	46.5
Abra nitida				8	
Abra prismatica				2	
Balcis alba				1	
Chlamys opercularis				1	
Cochledesma praetenue				15	
Corbula gibba				12	
Cultellus pellucidus	*		40	61	65.6
Donax vittatus				1	
Dosinia exoleta	*		10	57	17.5
Ensis ensis				17	
Gari fervensis	*		8	31	25.8
Lucinoma borealis				9	
Macoma balthica				3	
Modiolus modiolus				1	
Mya arenaria				1	
Mysella bidentata				471	
Natica alderi				25	
Nucula turgida				3	
Nucula hanleyi				57	
Spisula elliptica				84	
Tellina donacina	*		2	14	
Tellina fabula				1	
Thracia phaseolina				29	
Thracia pubescens				28	
Turtonia minuta				6	
Venerupis rhomboides	*		12/	25	40.0
Venus ovata					
Venus striatula	*		4	25	

(/ Including 2 dead)

TABLE 1 (Continued) (4)

Species	Identi-field thus on board (*)	Identi-fied further in labora-tory (*)	Numbers found on board	Numbers found in labora-tory	% Recovery on board
Ensis sp.	*	*	10	(17)	58.8
Natica sp.	*	*	10	(25)	40.0
Nucula sp.	*	*	1	(60)	
Philine sp.	*		1	24	
Spisula sp.	*	*	15	2(+ 84)	17.4
Pectinidae				1	
Bullomorpha				7	
Nudibranchia				4	
Loricata				2	
	12		153	1151	13.3
PHYLUM ECHINODERMATA					
Amphiura filiformis				51	
Astropecten irregularis				6	
Echinocardium caudatum	*		2	5	
Echinocyamus pusillus	*		3	42	
Ophiothrix fragilis	*		2	2	
Ophiura albida				82	
Ophiura texturata				1	
Psammechinus miliaris	*		4	6	66.7
Spatangus purpureus	*		1	1	
Ophiura sp.	*	*	20	(83)	24.1
Cucumariidae	*		7	59	11.8
Echinoidea	*		1	1	
Ophiuroidea	*	*	60	1(+ 51)	
	9		100	257	38.9
OTHER PHYLA					
PORIFERA				1	
NEMERTINI	*		8	200	4.0
SIPUNCULOIDEA	*		4	7	57.1
'GEPHYREA'				16	
Flustra folicea				10	
Flustra sp.	*		1		
POLYZOA				1	
TUNICATA	*		16	131	12.2
Callionymus lyra	*		1	1	
	5		30	367	8.2

TABLE 2

OVERALL COMPARISON OF ON-BOARD AND LABORATORY ASSESSMENT

	On-board (rapid) assessment	Laboratory assessment
Total number of animals found	257	11200
Total number of species* found	61	126
Man-hours taken to pick out, identify, and record animals	10	280

*Including separated groups, e.g. families

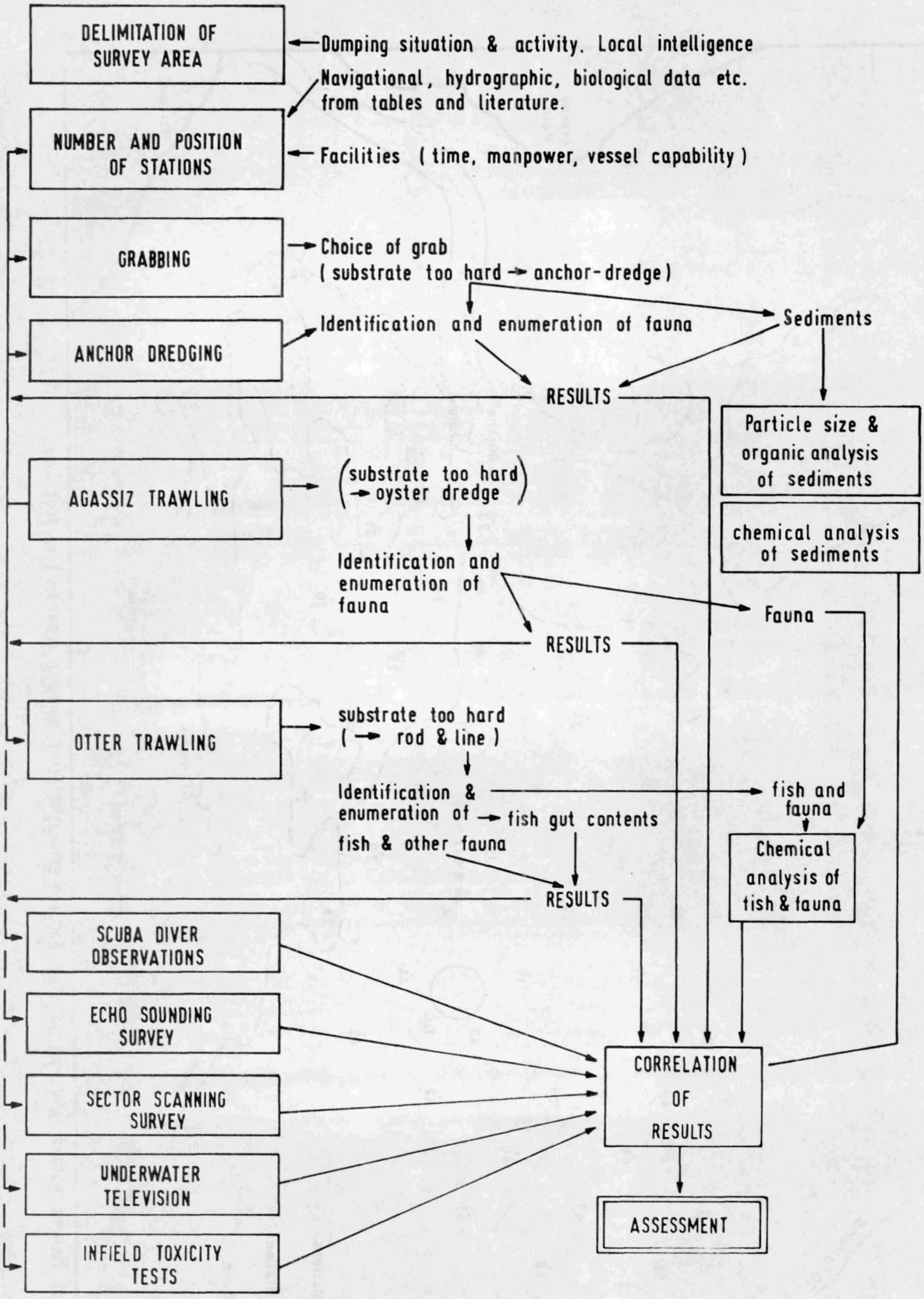


Figure 1 Procedure for rapid field assessment

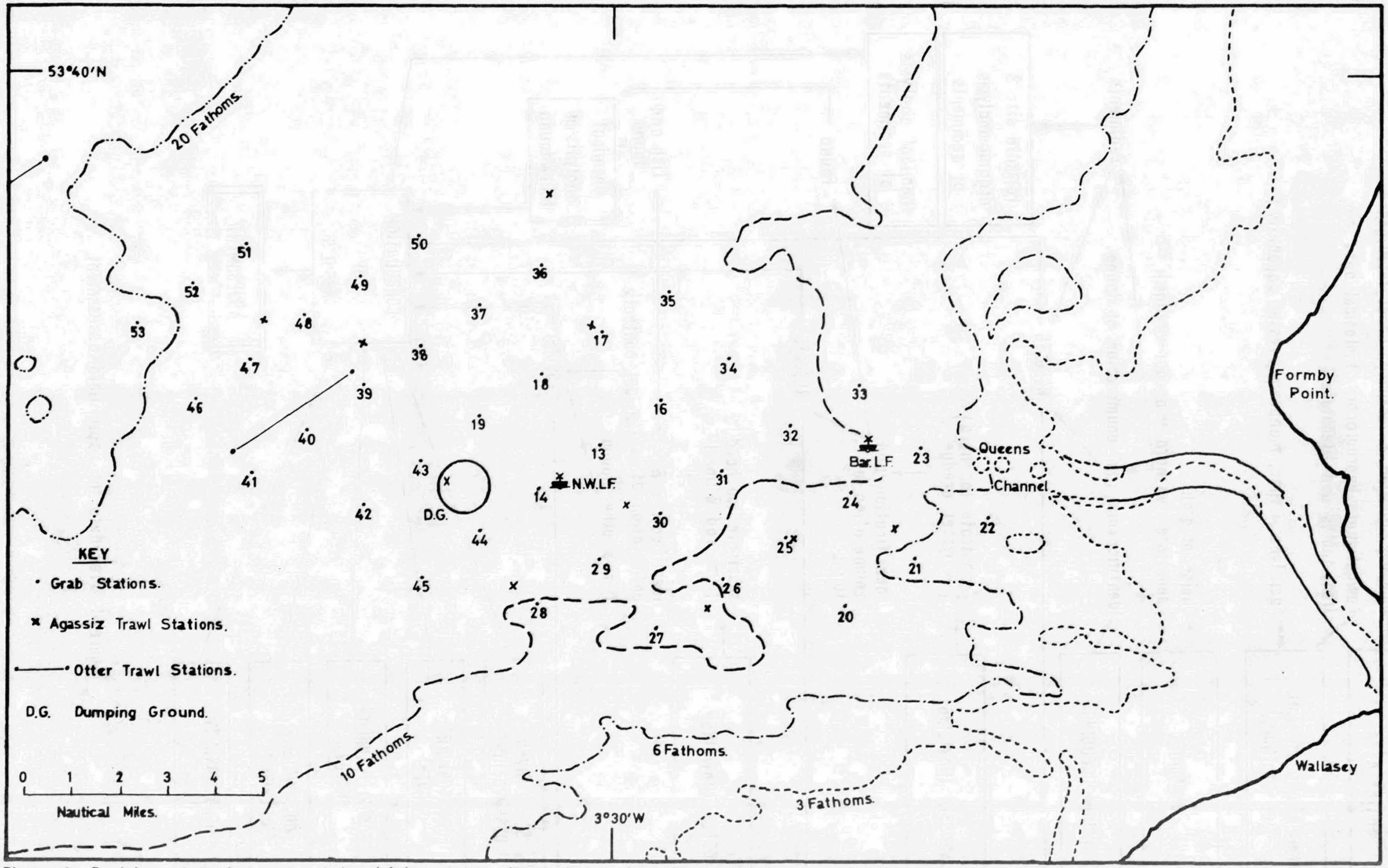


Figure 2 Position of stations worked in vicinity of the North-West Light Float dumping ground, Liverpool Bay

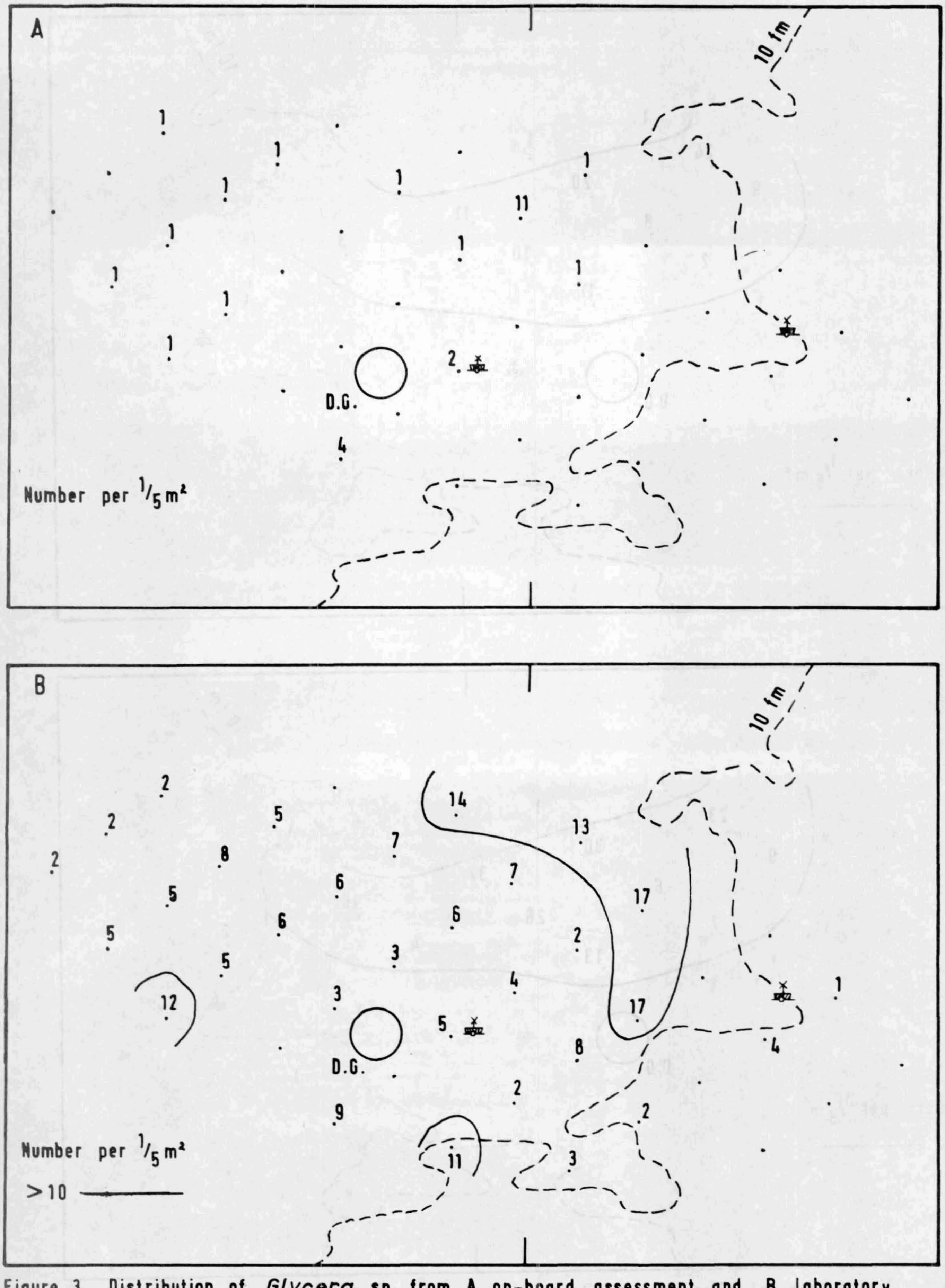


Figure 3 Distribution of *Glycera* sp from, A on-board assessment and B laboratory assessment

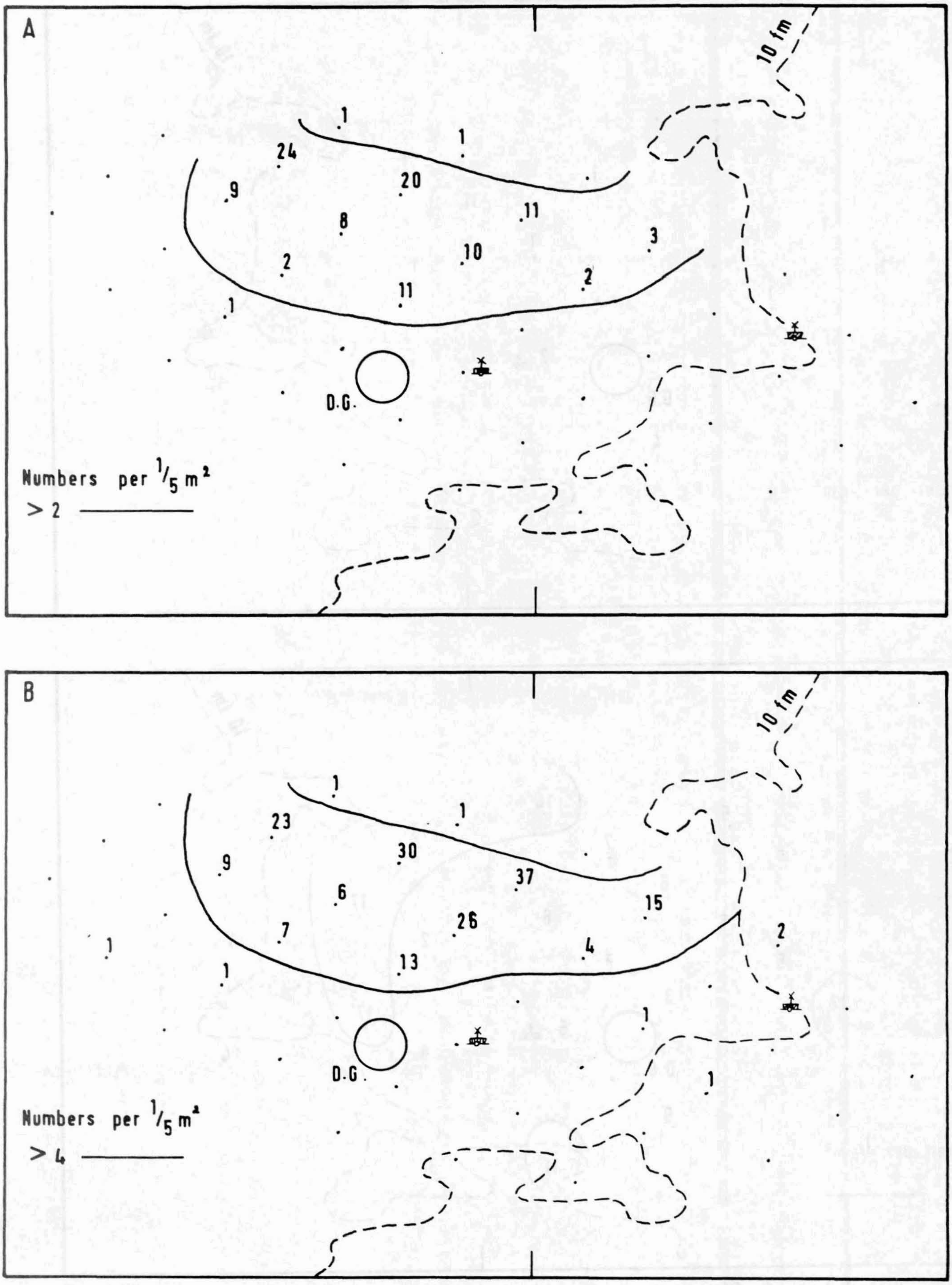


Figure 4 Distribution of *Owenia fusiformis* from, A on-board assessment and B laboratory assessment

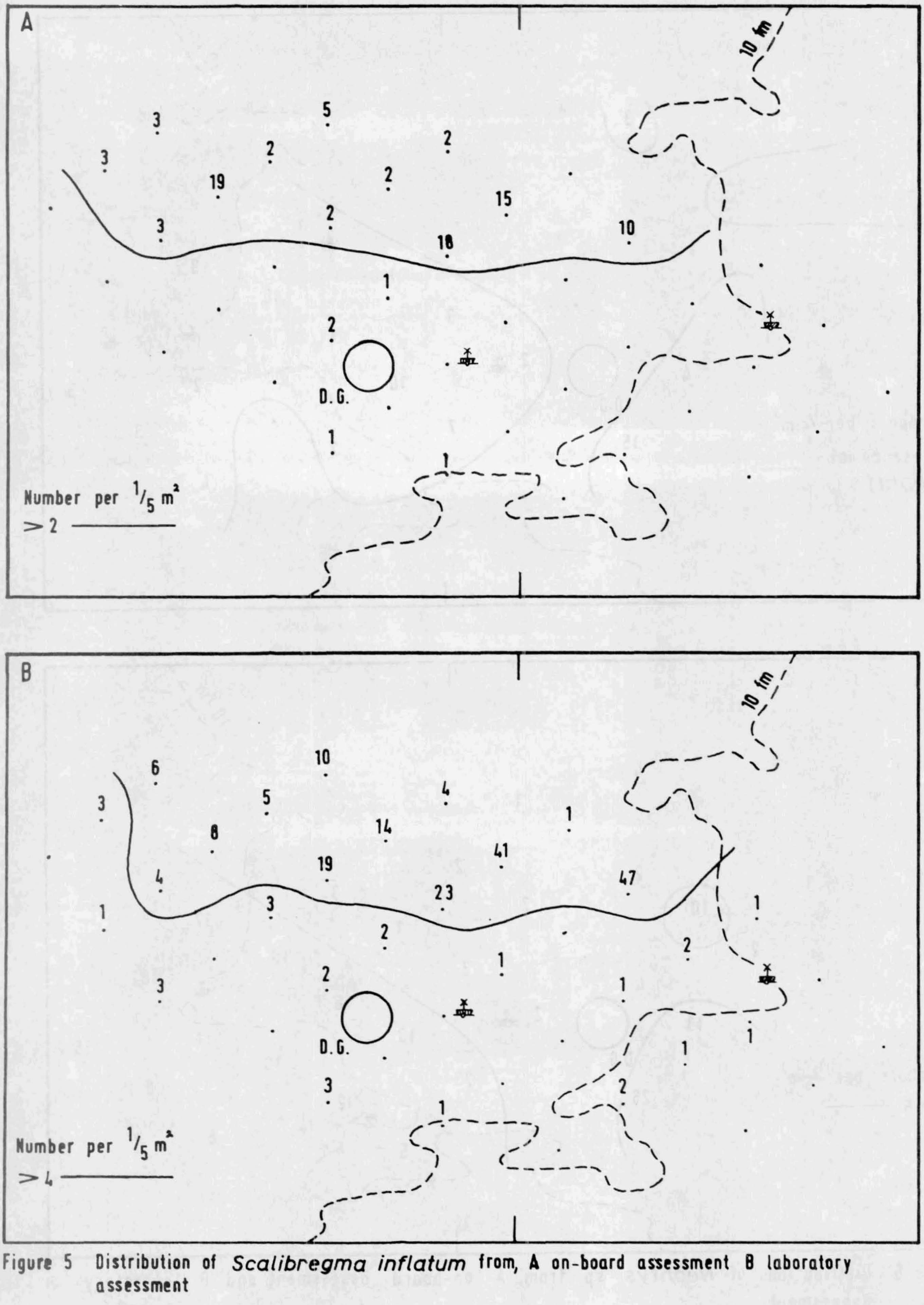


Figure 5 Distribution of *Scalibregma inflatum* from, A on-board assessment B laboratory assessment

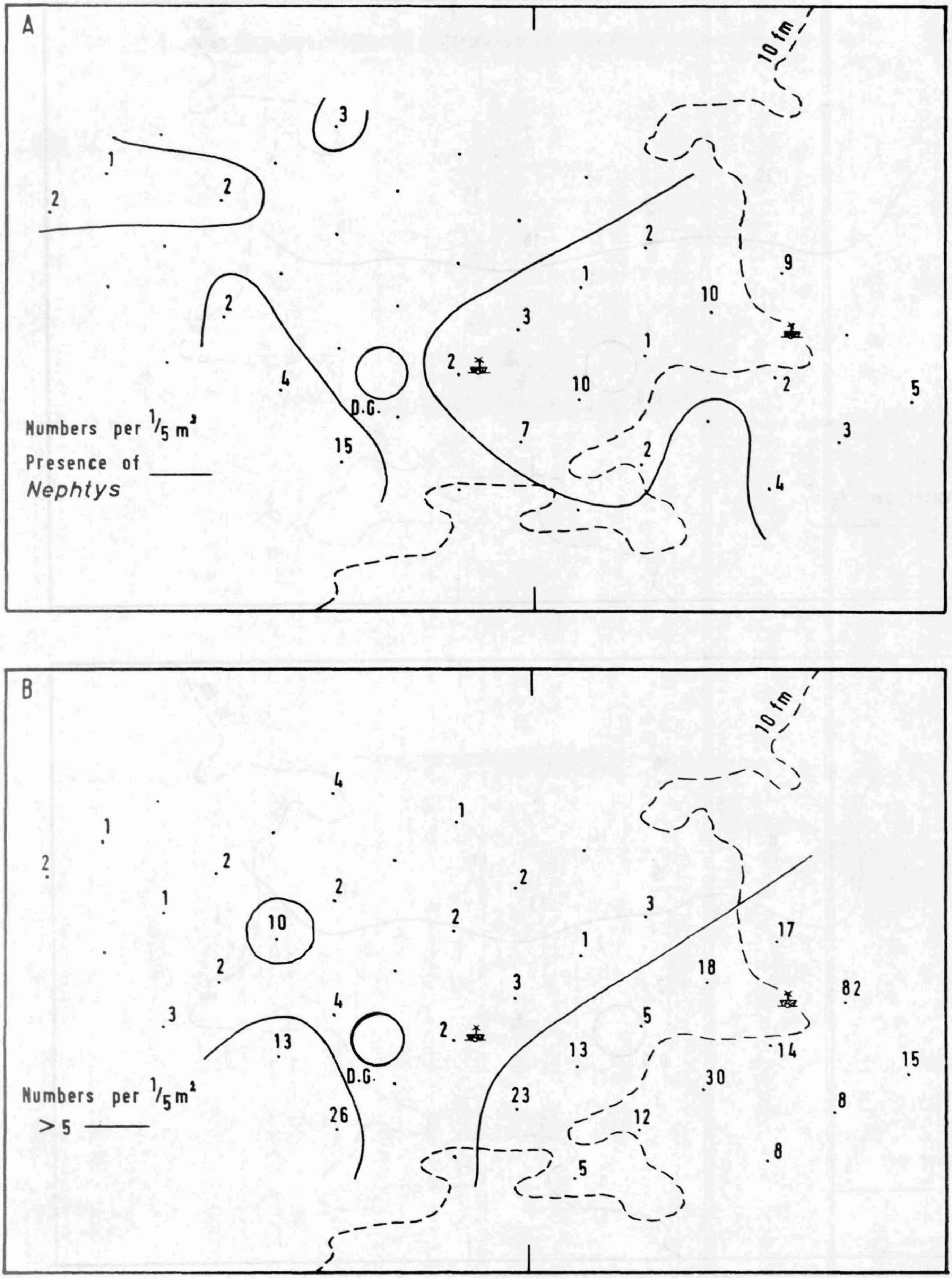
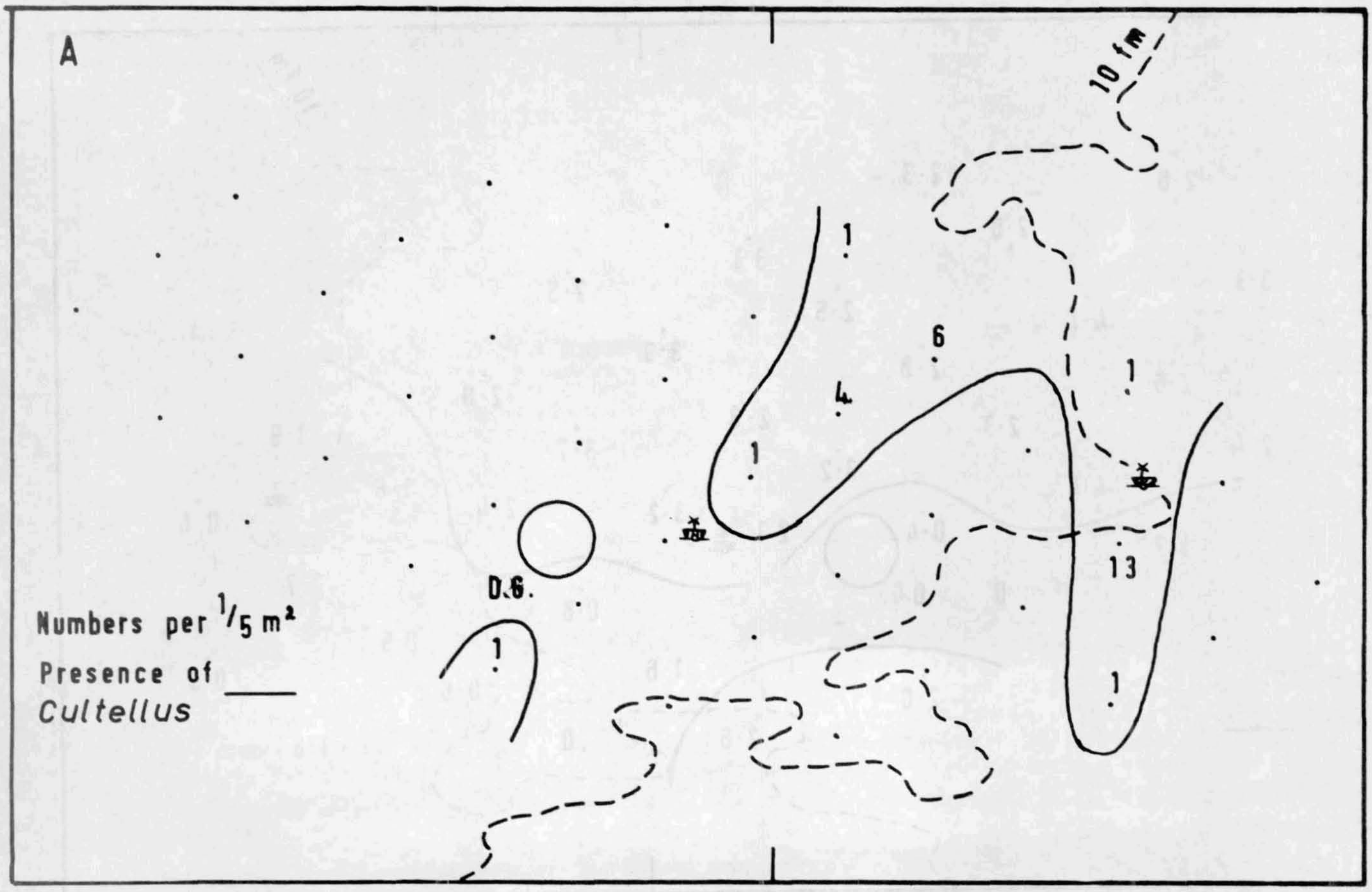


Figure 6 Distribution of *Nephtys* sp from, A on-board assessment and B laboratory assessment



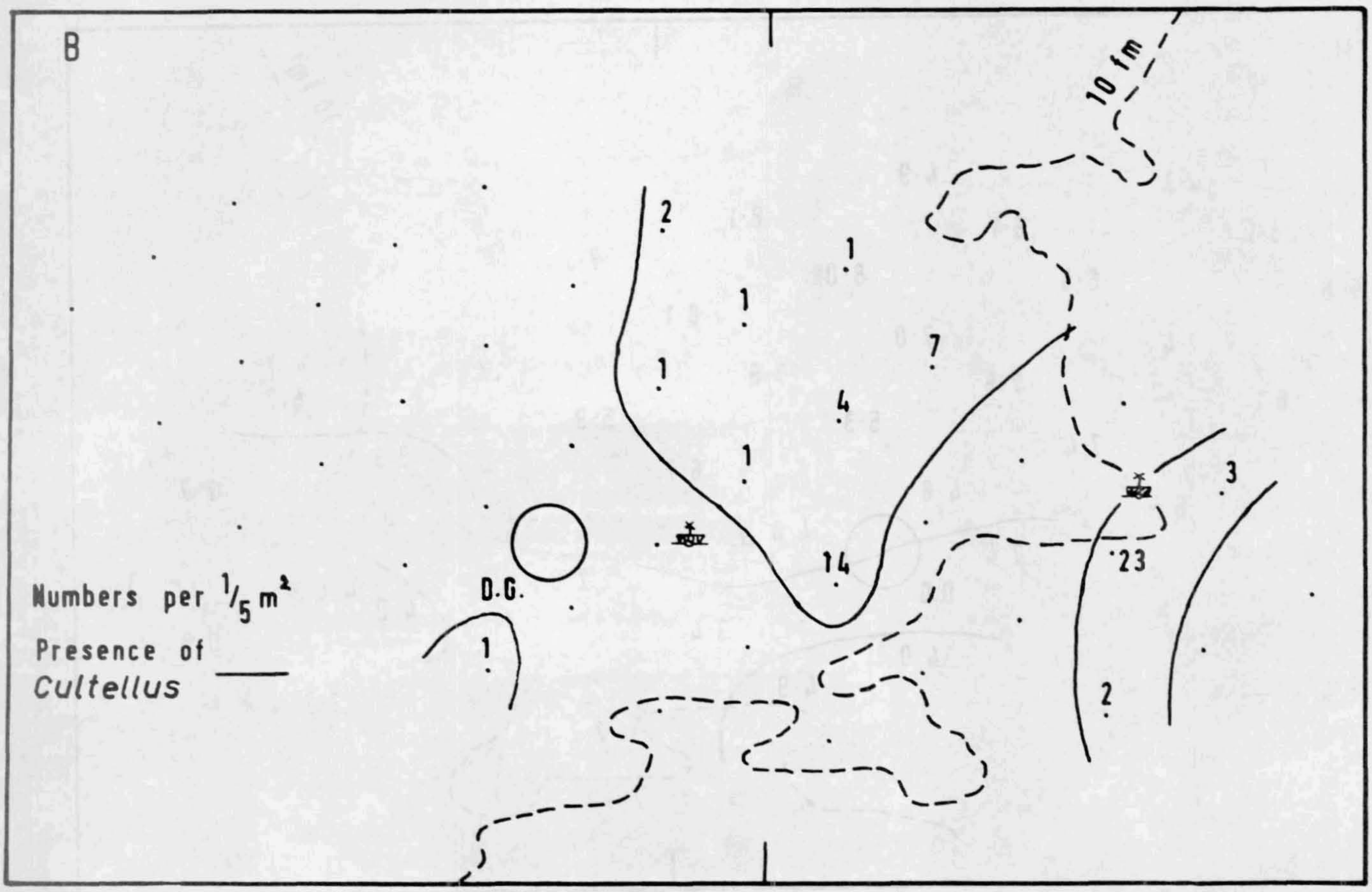


Figure 7 Distribution of *Cultellus pellucidus* from, A on-board assessment and B laboratory assessment

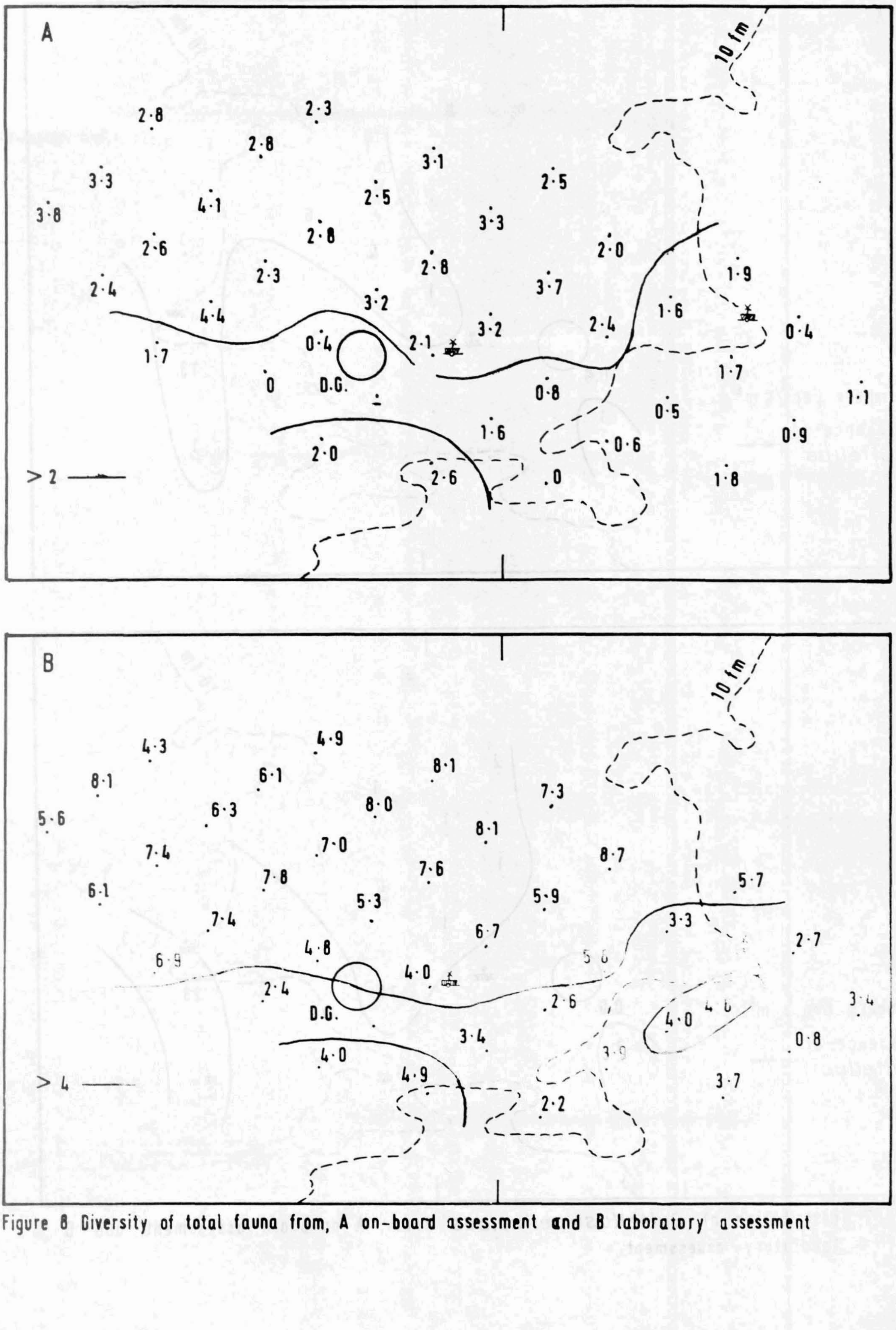


Figure 8 Diversity of total fauna from, A on-board assessment and B laboratory assessment