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Use of Small Otter Trawls in Coastal Biological Surveys

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USE OF SMALL OTTER TRAWLS IN COASTAL BIOLOGICAL SURVEYS[1]

by

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FOREWORD

Effective regulatory and enforcement actions by the Environmental Protection Agency would be virtually impossible without sound scientific data on pollutants and their impact on environmental stability and human health. Responsibility for building this data base has been assigned to EPA's Office of Research and Development and its 15 major field installations, one of which is the Corvallis Environmental Research Laboratory.

The primary mission of the Corvallis laboratory is research on the effects of environmental pollutants on terrestrial, freshwater, and marine ecosystems; the behavior, effects, and control of pollutants in lake systems; and the development of predictive models on the movement of pollutants in the biosphere.

This report presents a review of techniques for using otter trawls to survey demersal fish and invertebrate populations. The health and abundance of these populations is often used as an indicator of the biological effects of marine pollution.

A.F. Bartsch, Director
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ABSTRACT

Ecological surveys using small otter trawls provide useful and informative data on demersal fish and epibenthic macroinvertebrates of coastal soft bottom areas.

This report presents recommendations for selecting and using small otter trawls in coastal biological surveys and suggests methods for handling catches and processing data.

Use of small trawls in monitoring surveys is an adaptive use of their original purpose in commercial fishing. Many investigators have made effective use of small trawls in ecological surveys and some of this work is reviewed.

Nets ranging in headrope length from ten to sixteen feet are recommended for shallow waters, estuaries, lagoons and aboard small boats; twenty-five foot nets are recommended for open coastal areas.

Use of the gear, accessory gear and care and trouble-shooting procedures are described. Some aspects of survey design, data summarization and data analysis are reviewed. The report covers a period from March 1975 to March 1976; work was completed May 1978. This report was submitted in partial fulfillment of EPA Grant No. R801152 by the Southern California Coastal Water Research Project, El Segundo, California, June 1975.

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FIGURES

ACKNOWLEDGMENTS

Biologists, field personnel and skippers from many local public and private agencies contributed useful comments and suggestions toward this report and the recommended procedures. We particularly appreciate the assistance and collaboration of field staff from the Sanitation Districts of Los Angeles County, Los Angeles City, and Orange County. Mr. Jim Willis, netmaker, Morro Bay, California, contributed important suggestions and gear modifications. Messrs. Harold Stubbs and Michael Moore, of the Coastal Water Research Project, are due particular thanks.

SECTION I

CONCLUSIONS

One of the first questions asked by the public about marine pollution studies is "how are the fish?" Thus, ecologists surveying coastal marine communities should become familiar with methods for surveying epibenthic fish and invertebrate populations.

Small otter trawls have been used by a number of investigators to survey abundance of bottom fish, crabs, shrimp, and other larger invertebrates. While there may be considerable quantitative variations among catches, statistics from entire surveys do show general trends and can be useful contributions to an overall ecological assessment.

Diseased and abnormal fishes occur in some coastal areas. Surveys using small otter trawls are a useful way of making a quantitative assessment of disease types and frequencies.

There are no published standard procedures for using small otter trawls in coastal survey assessment and the effect of variations in gear, gear use procedures and gear trouble shooting are not well understood. This report summarizes how to use small otter trawls, how to identify when gear is not working properly and how to make adjustments frequently needed aboard ship.

There are also no standard procedures for summarizing data from small otter trawl surveys. Therefore, this report recommends some methods that have proved useful in southern California coastal surveys.

SECTION II

RECOMMENDATIONS

The objective of otter trawl sampling should be to assess in a standardized fashion the relative abundance, diversity, and health of all available fishes and larger invertebrates living on or near the bottom. The objective does not include catching as many fish as possible; generally 200 to 1000 animals representing 20 to 30 species are more than adequate to assess dominant biological characteristics of samples.

Single-warp otter trawls ranging in headrope length from ten to sixteen feet are recommended for shallow waters, estuaries, lagoons and aboard small boats; twenty-five foot nets are recommended for deeper open coastal waters. Body mesh of the nets should not exceed 1.5 to 2.0 inches, stretch mesh and the cod-end should be fitted with fine-mesh liners (0.25 or 0.5 inch, stretch measurement) to retain juvenile fishes. Trawls should be fitted with chain or lead weights on the foot rope, attached to a pair of doors or otter boards fitted with steel shoes and towed by a pair of swivel-mounted bridles that are three times the headrope length.

Towing time and rate should be standardized, e.g., 10 minutes on bottom time at 2.5 knots along isobaths. Trawl scope ratios should range from 5:1 in very shallow water (5 to 20 meters) to 2:1 in very deep water (700 to 900 meters).

Recommendations for setting gear, hauling, retrieval, and trouble-shooting are given in the text together with methods for quickly sorting and measuring catches and summarizing data.

SECTION III

INTRODUCTION

The use of small shrimp or otter trawls for assessing demersal fish and invertebrate populations is an important and informative addition to other kinds of water quality and faunal surveys. This report summarizes criteria for the use of otter trawls for sampling coastal areas and suggests guidelines for collecting and interpreting data from otter trawl surveys.

APPLICATIONS OF TRAWL SURVEYS

While benthic infaunal surveys (e.g., Holme and McIntyre 1971) provide a quantitative assessment of local ecological effects, trawl surveys have the potential for relating local patterns of the health, diversity and abundance of bottom fish to larger-scale regional trends. Trawl surveys also deal more directly with organisms of economic importance (e.g., shrimp, flatfish) and with a properly experienced staff,organisms captured by trawl can be readily identified, examined and returned overboard in the field, thus minimizing laboratory effort and maximizing analysis of data in a short period of time. Trawl surveys do not replace other kinds of biological surveys, but they do add to the total ecological description of a coastal fauna.

Trawls were developed empirically through many years of fishing experience. They have been designed to select, capture and retain various kinds of organisms in commercial quantities. Thus their use in ecological monitoring is relatively new and is developing rapidly so that choice of gear and gear use procedures remain an empirical problem based on each new experience. The papers selected for the bibliography of this report reflect the variety of gear, use procedures and objectives, and findings resulting from recent coastal otter trawl surveys. The latter include assessment of pollution-related diseases, assessing background data on communities and describing general effects of pollution on fish populations.

LIMITATIONS OF GEAR AND PROCEDURES

As quantitative sampling devices, otter trawls are not free of insufficiencies and biases. Efficiencies of capturing and retaining animals are very low, probably on the order of 10 to 50 percent, depending on the abilities of various organisms to avoid gear or pass through the webbing, or on towing conditions, sea state and weather. And, with the exception of major fishery resource surveys, trawl gear and gear use procedures for monitoring have never been standardized; agencies involved in monitoring surveys use different sized nets, with different mesh sizes, different towing speeds, towing times and retrieval procedures. This does affect the regional value of data if gear and gear use procedures are not adequately defined in reports from surveys.

CRITERIA FOR RECOMMENDING GEAR AND PROCEDURES

The guidelines suggested below are based on our own five year experience in sampling the open coastal shelf of southern California with a variety of otter trawls, agencies and ships. Additional literature was consulted to evaluate experiences in other environments.

Use of the techniques recommended should provide a general informative semi-quantitative data base for describing the health, diversity and abundance of benthic fishes and invertebrates not readily quantified by other methods. Experience with the methods will show where gear and gear use modifications need to be made to conform to local conditions, terrain and weather.

SECTION IV

SAMPLING

SAMPLING OBJECTIVES

The objective of otter trawl sampling is to assess in a standardized fashion the relative abundance, diversity and health of all available fishes and invertebrates living on or near the bottom. This objective can only be met if variations in gear and gear use procedures (towing time or distance covered, speed) are minimized by adopting standardized gear and ocean survey procedures.

The objective does not include attempting to catch as many organisms as possible; experience indicates that individual catches on the order of 200 to 1000 animals (fishes and invertebrates) representing 20 to 30 species are more than adequate to assess the dominant biological characteristics of the samples.

TRAWL SAMPLING GEAR

A trawl is a cone-shaped bag of netting towed in the water column or on the bottom by one or two vessels. The term otter trawl, or otter board trawl, is generic and separates nets with variable mouth openings from fixed opening gear, such as beam trawls.

Types of Nets

Although there are a variety of commercial otter trawls available, those used most frequently for monitoring surveys are small (10 to 40 foot openings) and adapted from commercial gear; shrimp trawls and trynets are the most frequently used and are the main subject of this discussion. Beam trawls may be valuable in some shallow water situations and for accurate quantification of juvenile flatfishes (Holme and McIntyre 1971) but are generally less efficient for larger fishes, shrimp and other animals active just off the bottom. The advantage of beam trawls is that their opening remains constant.

Important features of a rigged otter trawl are shown in Figure 1 and are described in more detail by Hodson (1967) and Garner (1962). Most available otter trawls include a set of otter boards or doors which when attached to net-wings by each pair of leg-lines, serve to spread the net during towing. The top leading edge of the net (headrope) is held up by a row of four to eight floats, and the lower leading edge held down by a foot-rope chain or lead weights which are closely attached to the net. The cod-end, which retains captured fish and invertebrates, should be fitted with a 1/2 or 1/4 inch stretch mesh liner. Garner (1962) presents a useful detailed glossary of terms and gear.

Single warp (i.e., towed by a single cable, Figure 1) otter trawls ranging in headrope length from eight to sixteen feet (about 3 to 5 meters) are recommended for use in shallow coastal waters (e.g., to 50 ft. deep), estuaries, tidal lagoons and bays. Nets of this size range are also suitable for use in small boats (14 to 25 feet).

For general use in open coastal waters, 16-, 25- or 30-foot single warp otter trawls are recommended. Body mesh of the nets should not exceed 1.5 to 2 in. and the cod end (Figure 1)

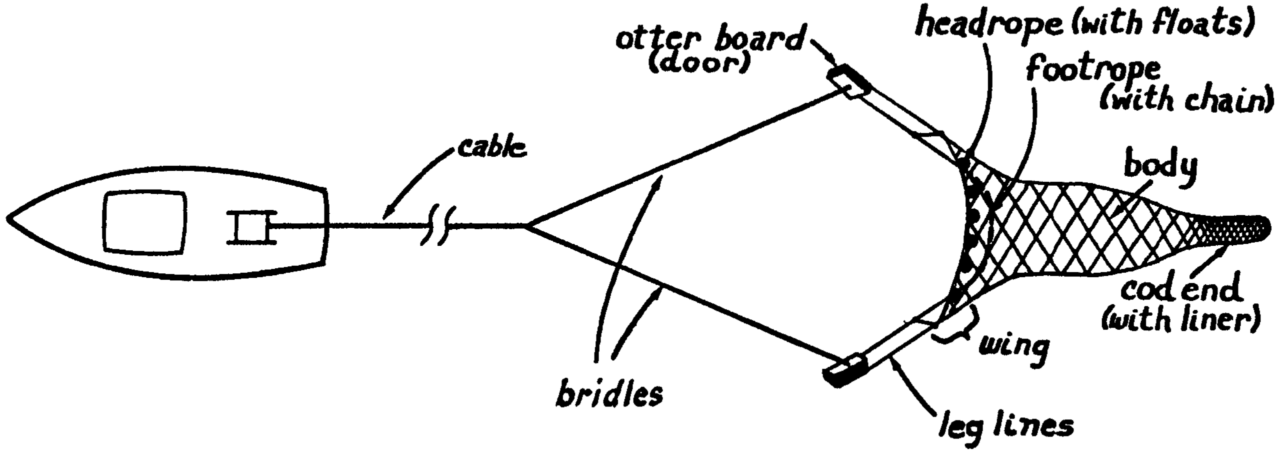


Figure 1. Basic features of a small otter trawl under tow.

should be fitted with fine mesh (0.25 or 0.5 in.) liners to retain juvenile fishes.

Accessory Rigging

Most otter trawls are fitted with a heavy chain or lead weights on the foot rope. The function of this added weight is to keep the bottom leading edge of the net on or near the bottom during towing. Nets with weights on the foot rope tend to sift through bottom sediments thus capturing large quantities of starfish, sand dollars and sea urchins when they are present. Chain-rigged nets are more versatile and can be adjusted to avoid this "epibenthic" fauna or to capture and retain it. The investigator should be aware of these considerations in planning his sampling program and objectives.

Otter boards also have special attributes and require experience for proper adjustment and rigging. The boards should be fitted with a "shoe" (i.e., a heavy iron strip covering the leading and bottom edge). Boards fitted with four rather than one or two towing chains are also recommended since these can be individually slackened or tightened to adjust the angle of attack of the boards. These adjustments are described in a section below.

The trawl should be attached by a pair of bridles to a three-way swivel on the end of the towing cable. The length of the bridles should be about three times the headrope length (and not less than two) for proper spread of the otter boards.

Steel or stainless steel towing cable (1/8 to 3/8 in.) on a hydraulic winch is recommended over nylon or polypropylene line for towing and retrieving the trawl. The maximum length of towing cable required aboard the boat should be at least four and preferably five times the maximum depth anticipated.

The "scope ratio" (ratio of cable plus bridle length to depth) during towing decreases with depth. For very shallow water (5 to 20 meters) the ratio should be 4 or 5:1; at coastal shelf depths (20 to 50 meters) a scope of 4:1 may be the maximum needed. Beyond 50 meters scope ratios may decrease as follows: 3 to 3.5:1 at 100 - 200 meters; 2.5 to 3.0 at 200 to 350 meters and 1.8 to 2.1:1 at 700 to 900 meters.

Running Gear

In addition to a hydraulic gasoline or electrical winch with sufficient cable, other shipboard equipment should include a davit and pulley for assisting retrieval of heavy catches, a live box with flowing water for holding and sorting fishes, a sorting table and a recording fathometer for monitoring depth changes and obstructions. Some accessory gear for a small boat is described by Baldwin (1961).

Shooting and Retrieval

Methods of releasing ("shooting") and retrieving a trawl are important to proper functioning of the gear. Prior to shooting, the ship skipper should make one pass over the desired trawl site, watching for depth changes, obstructions, and fish targets. If the site is appropriate, the vessel should move a sufficient distance from the starting point so that the net will touch bottom at the desired location after shooting and lowering the gear.

The net is laid out on the stern deck in the form it will be shot. It should be checked first for twists, snags, or broken twine/floats. The boards, placed in normal fishing position, should be shackled to the leglines, then to the coiled bridles. Care need be given to avoid crossing any portion of the starboard leglines and bridle with the port-side lines. A 4 to 5-foot fine twine rope can be used to secure the cod end. A quick release knot is best, with at least three bindings.

The net is placed in the water as the vessel approaches station start location. Two deck hands, standing to the outside of the bridles, launch the boards on notice from the skipper while the vessel is in motion. By carefully metering out the bridles, the boards can be encouraged to spread on the surface. The net should show the configuration of the rig and possible torquing or alignment problems while on the surface before cable is let out. If excessive torque or twists are observed, retrieve the net and adjust or replace it.

Scope (length of cable out ÷ depth) should be calculated beforehand and called out to the winch operator as the trawl rig descends. If available, an angle-measuring device can be used to check the wire angle and to verify scope.

On deck, while trawling, the winch operator should report any unusual tension or slack in the cable while the skipper should be asked to record time and date and station number, preferably on a recording fathometer read-out. The skipper signals the winch operator when the appropriate on-the-bottom time is up and records the time. The winch operator should haul in the net while the boat is advancing at trawl speed.

The otter boards should break the water together but not be twisted together. Retrieving the trawl gear will vary with vessel equipment. If more hauls are to be made, then care should be given to stacking the bridles, boards, and net neatly for the next station.

Consult Hodson (1967) for additional information on shooting trawl nets.

Care and Troubleshooting

After hauling out the last catch of the work period, the boards can be removed with the bridles. Wear on the board shoes should be observed; i.e., the shoe wear pattern should verify that each door was tilted forward and "toeing in" when riding over the bottom (Figure 2). Bridles should be tied together on a cleat to check that their lengths are equal. Unequal stretching can cause torquing or tangling of the net and impair fishing configuration.

The net can be tied off on the stern to wash during return to port. At dockside, it should be rinsed off with fresh water and laid out in a safe, secure place to dry.

Leadline, floatline and meshes on the net should be checked occasionally for slippage of knots and tears. Repairing rips and holes should be done when observed by cutting rough edges off a tear and sewing in a square patch of appropriate webbing over the hole. Drawing tears together without using patch-webbing can tighten the net excessively in one spot causing distortion (see Hodson 1967).

Broken floats should be replaced with new plastic floats sewn onto the headrope by an additional loop of rope and not directly onto the headrope itself. Floatation varies with headrope length; a 25-foot net is generally equipped with five to six floats concentrated toward the center of the headrope.

If the boards are not spreading properly or not attacking the bottom at the correct angle, they need adjustment. The adjustment could be in changing legline length between the legs and doors or by adjusting chain lengths on the boards. The following chain adjustments have been found useful for 25-foot nets (Figure 2):

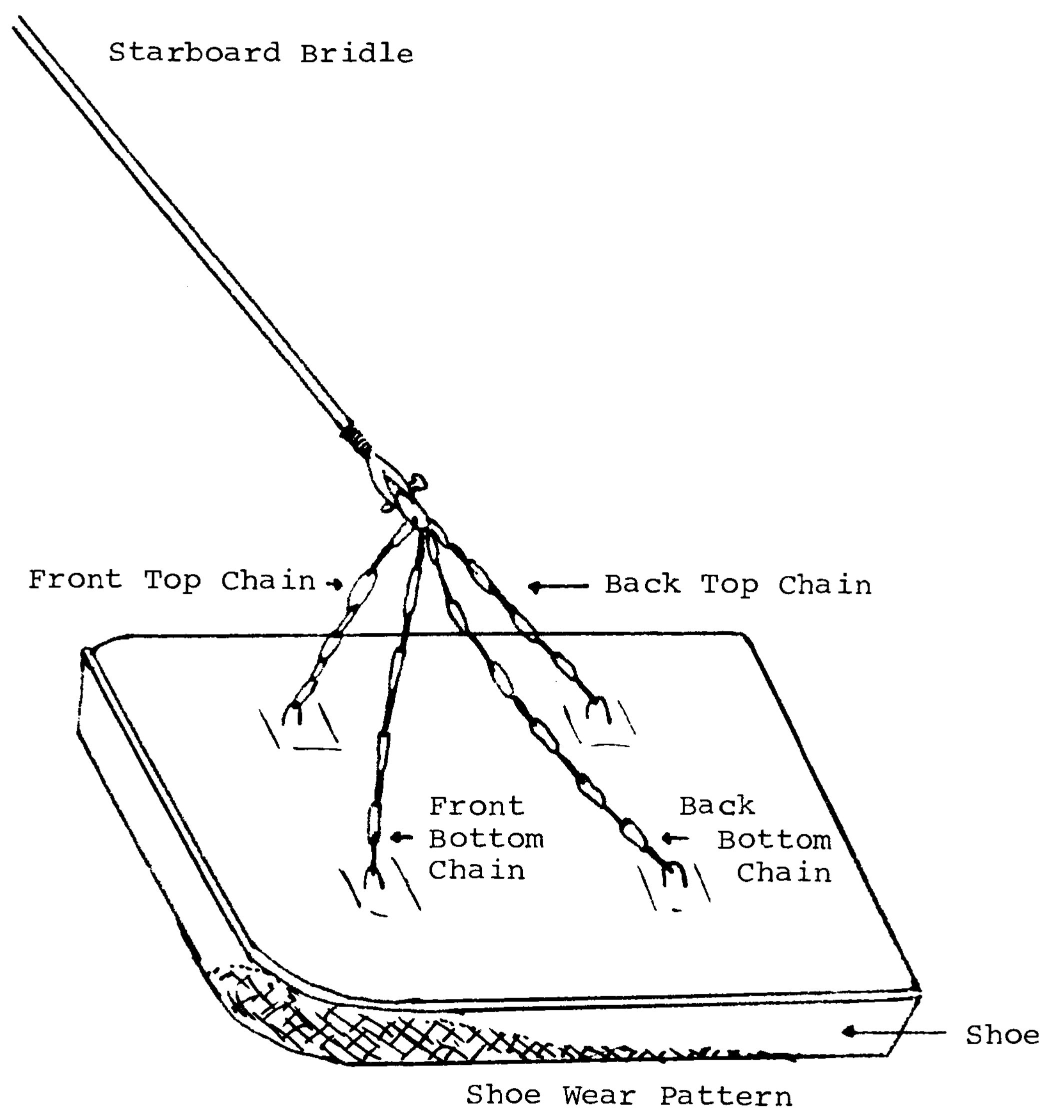


Figure 2. View of an otter board. Note wear pattern on shoe.

At normal trawling speeds (1.5 to 3 knots), the tendency should be for the doors to "toe" or tilt forward. If the door is not digging enough (i.e., shoe bottom is wearing equally from front to back), take up one link on the rear bottom chain. If still not steep enough, slack off one chain on the top front chain. If the board is "riding-on-toe" (tilting too far forward, thus raising the legline and footrope off bottom), take up on the top legline rope about two inches per adjustment. If the board is angling too sharply backward (heeling, e.g., shoe wear is all in the back of the shoe), slack off on the top legline or take up slightly on the bottom legline. Wear on the shoe can be readily observed by spraying the dry shoe with flat-black fast-drying paint and examining wear pattern after retrieving the doors.

The spread of the net can often be observed as it leaves or approaches the surface. An estimate of actual door-to-door spread can be made during surface towing by calculation from measuring the angle of bridle spread, or the distance between bridles at a known distance from their juncture (Mearns and Stubbs 1974). Ketchen (1951) provides additional methods.

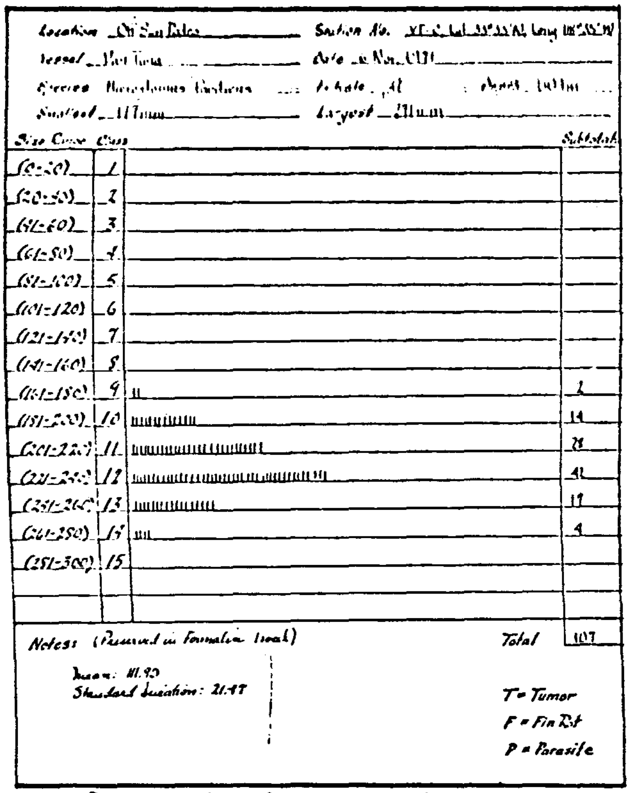
HANDLING, SORTING AND PROCESSING THE CATCH

The cod-end, containing most of the catch, is brought aboard last. It may be weighed using a spring balance on a davit to obtain a rough estimate of total weight and then opened and the contents shaken carefully into a large sorting box or a live tank. Care should be taken to remove all organisms that are stuck or gilled in the net before dropping the trawl on the next station.

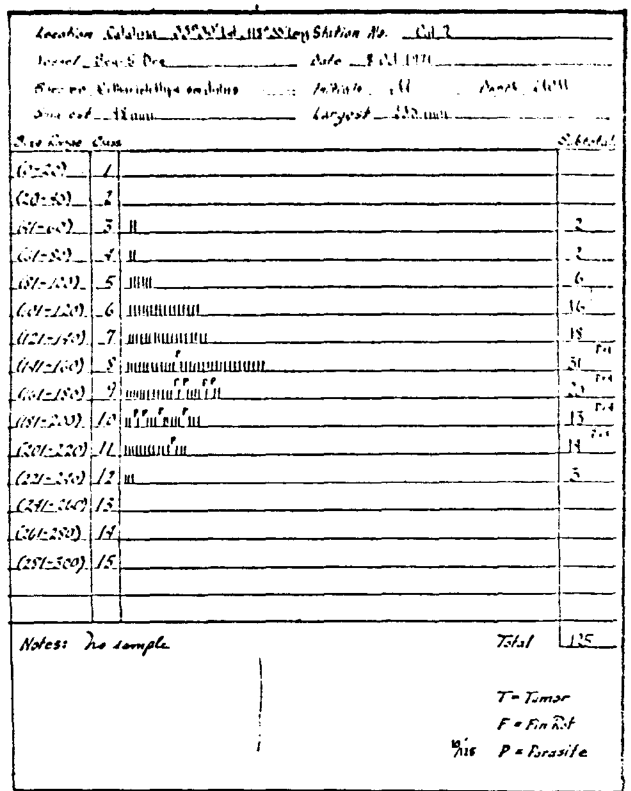
Animals should be roughly sorted by obvious species or higher taxons into large buckets partially filled with seawater prior to identification, counting and measuring. This helps to keep the organisms alive and also aids in sorting as they do not stick to each other. Fine sorting into species can then be done prior to measuring.

A minimum of two technicians is required to identify, count and measure fishes and large invertebrates, if this is to be done in the field. Generally, two teams of two to three people each (one or two identifying, measuring and counting and one recording) are desirable, one group for fish and one for invertebrates.

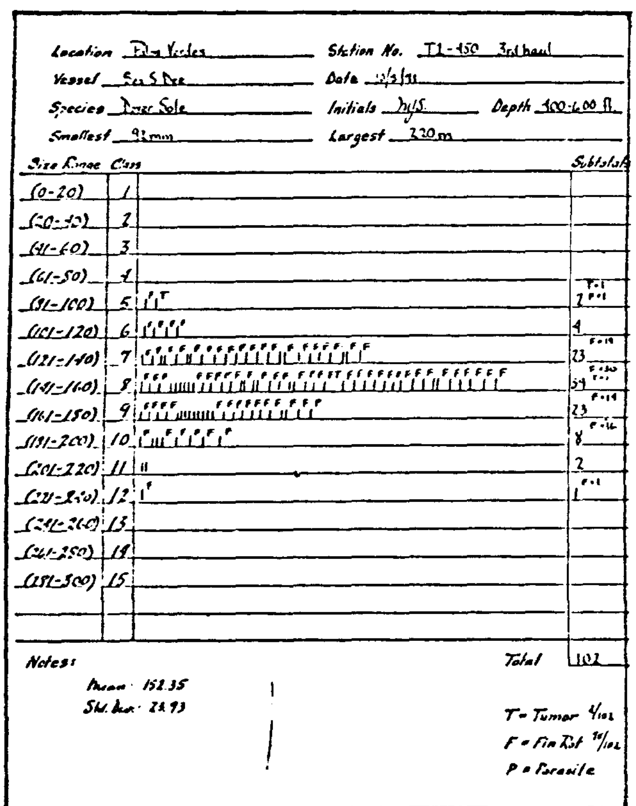
Where rapid identification is possible, technicians can simply and consecutively measure individual fish (to board standard length, B.S.L. or total length, T.L.), shouting out measurements to a recorder. Either the actual length of a fish to mm or a mark in a histogram data sheet (Davenport and Harling 1964 or Figure 3) can be entered and the total count for a species tabulated later (Anderson 1964 describes methods for selecting size intervals). During measuring, fishes should be examined for ectoparasites (including those in the gill cavity), deformities, tumors, frayed or apparently diseased fins, color variations and gross structural deformities (Figure 3). If specimens are to be saved for histopathological examination, they should be preserved in 10 percent phosphate buffered (pH 7.0) formalin together with a few apparently normal specimens from the same catch. Often, fish will show some external signs of bearing eggs or larvae or may have regurgitated food. Notes should be made from these observations. Again, specimens may be quick frozen or preserved in formalin (as above) for future examination of reproductive state or stomach contents. If this is to be done, it is advisable to preserve a range of sizes of a species; fishes larger than three to four inches should be slit along the lower right side of the abdominal cavity (by convention, symmetrical fishes are usually photographed on their left side) to allow preservation of the viscera.



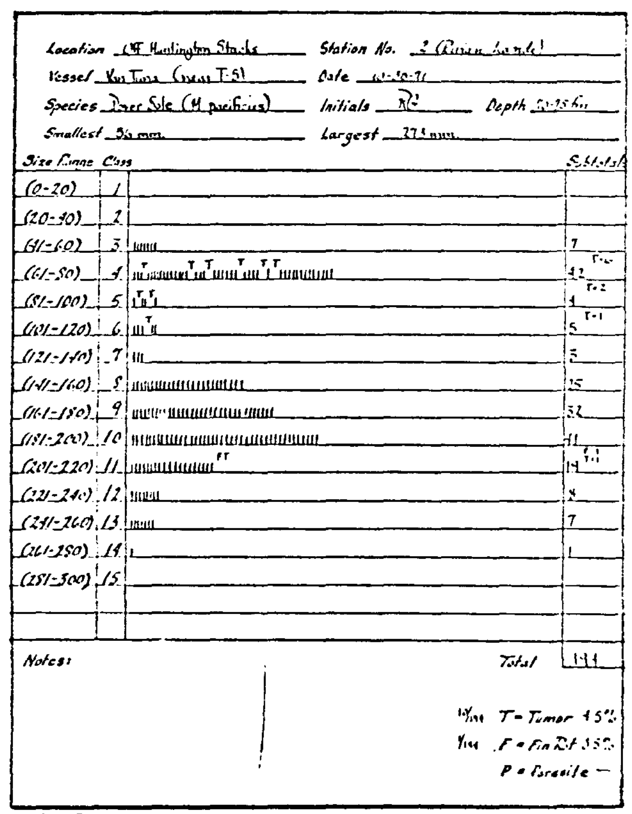
a. Dover sole, single population, no abnormal fish



b. Pacific sanddab, graded sizes, ecto-parasites on large fish only



c. Dover sole, primarily single population, high incidence of fin erosion.



d. Dover sole, at least two populations, tumors on small fish.

Figure 3. Examples of histogram-form field data sheets for recording size of a species.

Fishes and invertebrates to be used for analysis of trace elements or other pollutants should be gently washed in clean seawater and frozen in labeled packages (aluminum foil is used for specimens intended for hydrocarbon analysis; plastic bags for those used in metal analyses). Location, date, depth, species, time of capture and the recorder's initials should be on the package labels. Contamination is an important problem with many trace material measurements and experts on this subject should be consulted.

Invertebrates such as shrimp can be measured in the field (e.g., carapace length), but they may consume shiptime if abundant. In such cases, the animals are returned to the laboratory for identification and analysis. Often a variety of small invertebrates attached to rocks, cans and bottles, wood debris, and kelp holdfasts are encountered and should be preserved for later examination; the occurrence of such materials should be recorded since they may explain anomalous or apparently rare invertebrate species.

In the absence of a qualified taxonomist, appropriate taxonomic keys and field guides for marine organisms found in the survey area should be acquired before the survey. Species lists from previous surveys in the area can aid considerably in learning to identify the organisms.

ABIOTIC DATA

Information on trawl conditions (success of tow, sea state, weather and wind, occurrence of jellyfish, flotsam, etc.) should be noted together with date, time of tow, direction of tow, station location, number, and depth, trawl speed, and net type on a master log for each cruise.

At a minimum, a measurement of bottom and surface water temperatures should be made at each trawl location during the tow (using a calibrated bathythermograph, BT) or after the tow using a BT or a series of reversing thermometers. Surface and bottom water dissolved oxygen is also an important parameter to measure at each trawl site. Oceanographic accuracies to four or more significant figures are not necessary for these parameters unless needed for interpretation of current flow and structure. In open coastal areas, salinity is not important, except as an aid in interpreting identification of water masses (in which case oceanographic accuracy is required). However, in estuarine situations, bottom and surface water salinities (or through the water column) may be vital in interpretation of species distributions and patchiness.

SAMPLING STATIONS AND GRIDS

Several factors must be considered prior to determining the location and number of stations to be surveyed:

1. Size and topography of the survey area, especially knowledge of obstructions, reefs and other hazardous objects.
2. Depth contours and maximum and minimum depths of the survey area with particular attention to submarine canyons and peninsulas.
3. The location of "control" sites that are not expected to be influenced by existing or proposed discharges or structures.
4. The occurrence of similar surveys in adjacent areas or regions, past surveys, and the sampling methods employed.
5. Human and material resources for the survey.

Generally, eight to ten otter trawl samples can be taken on the open coastal shelf in a normal field working day with a crew of three to four technicians, one or two deck hands, and a skipper. Limiting factors include maximum depth desired, gear wear, and sea state conditions.

Depth (and depth-related hydrographic features) is probably the single most important factor affecting the distribution of demersal fish in open coastal areas that have relatively steep slopes. Thus, coastal survey grids should be designed so that sampling effort is divided equally among three or more depth intervals in both control and test areas. In shallower estuaries, distance from river or discharge sources and tidal fluctuations may be more important as well as day-night differences in the distribution of animals (e.g. Dahlberg and Odum 1970; Roessler 1965). Thus, the survey grid should include a transect of three or more stations located at intervals between freshwater sources and the mouth of the estuary. Sampling the same sites at night as well as during the day will be required in these habitats.

For a good survey grid at a coastal outfall or ocean dumping site (e.g. Carlisle 1969), locate stations according to at least three depth intervals (for example, 30, 60, and 120 feet) and along at least three transects laid perpendicular to shore or to depth contours (e.g. Carlisle 1969). An example is shown in Figure 4. All tows should be made along, rather than across, depth contours to avoid integrating animals from different depth zones.

Annual and seasonal changes are very important to document in any kind of fish survey work (e.g. Dahlberg and Odum 1970; Gallaway and Strawn 1974; McErlean et al. 1972). Thus, a survey site should be resampled for at least a year at maximum of three-month (quarterly) intervals; sampling more frequently will aid in refining seasonal trends in abundance, diversity and disease incidence.

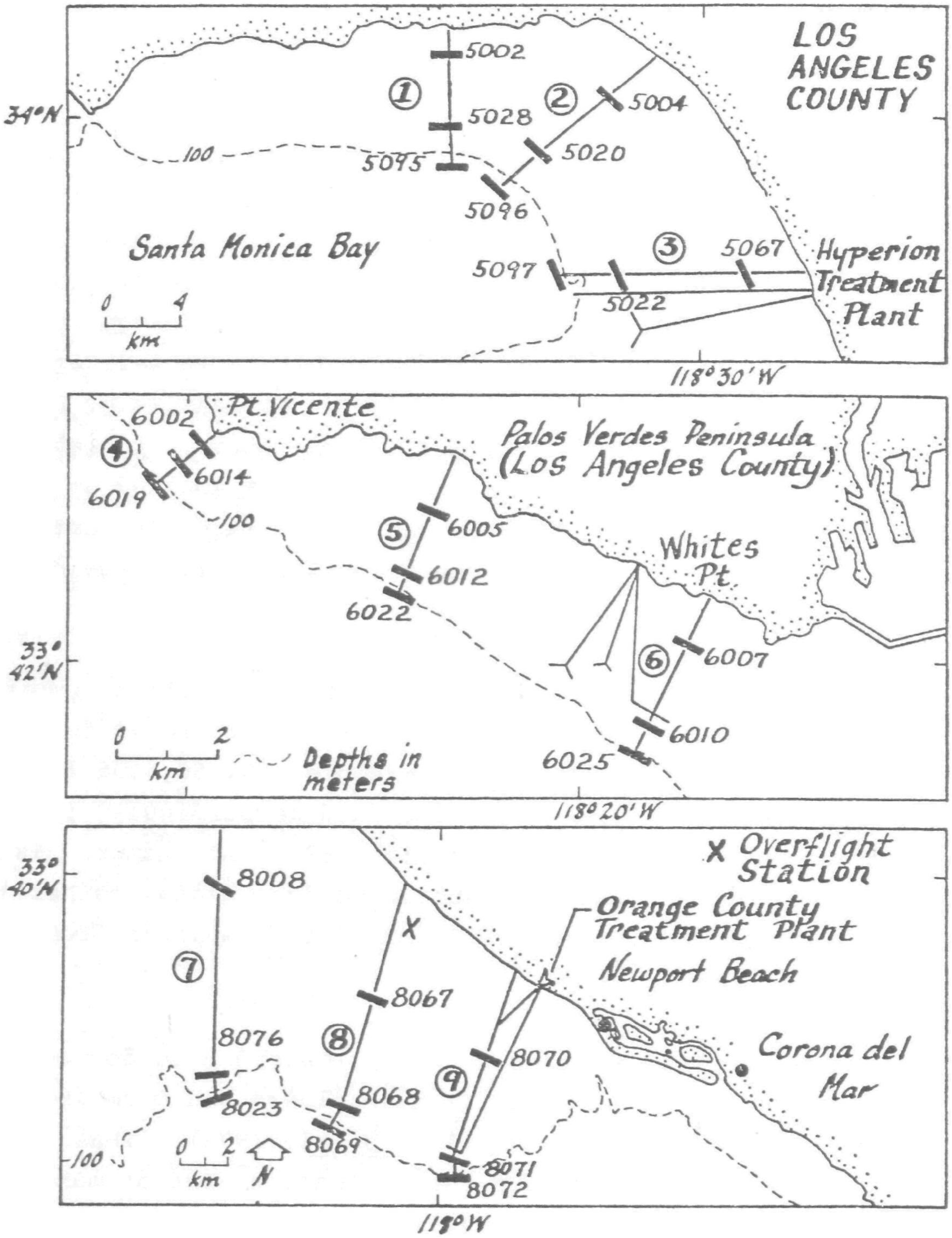


Figure 4. Station grids for trawl surveys in three coastal areas.

For coastal surveys, a single sample per station will generally suffice to document the common and dominant species and species associations. Replicate samples may show great variability with respect to total numbers of fishes or invertebrates, but will generally confirm the presence or absence of the common resident species (Roessler 1965; Clark 1974). For trawl surveys, then, the focus is generally not on estimating absolute abundances but on documenting presence and absence of species, relative abundances of species, size distributions and frequencies of anomalous organisms. In addition, repeated trawls over the same site within a few hours or days may itself affect the distribution of organisms. Rather than replication, we recommend additional effort be devoted to sampling additional stations until general aspects of the fauna are known.

Completion of a preliminary trawl survey prior to establishing a long-term monitoring program is well worth the effort; the kinds of organisms to be expected can be documented and their identification learned, the suitability of sites for trawling can be assessed and staff can become familiar with gear and gear use procedures.

SECTION V

DATA SUMMARY AND ANALYSIS

Data on a number of sampling, biological and abiotic (chemical and physical) variables will have been collected for each sample at the end of a trawl survey. The methods for summarizing, analyzing and reporting these data vary with the objectives of the surveys. Some recommended procedures are described in this section. Papers cited in the Bibliography should be consulted for additional suggestions on describing and reporting data.

DATA SUMMARIZATION

It is extremely important to summarize data in tabular forms which will allow ready access to biological and sampling variables. The variables of importance include:

<u>Sampling Variables</u>

a. sample location characteristics: longitude, latitude, depth, and time

b. tow characteristics: duration, direction, speed of tow, scope and length of bottom area covered

c. gear characteristics: size of net mouth (headrope length or door spread), mesh size, and bridle length

<u>Biological variables taken from individual organisms</u>

a. taxonomic identification

b. length

c. condition (disease or health state)

<u>Biological variables at the sample level</u>

a. species (number, taxonomic identification)

b. abundance (sample, species)

c. biomass (sample, species)

d. diversity (sample)

<u>Physical variables</u> (include water and sediment characteristics)

a. temperature (surface, bottom)

b. dissolved oxygen (surface, bottom)

c. clarity (Secchi depth or transmissometer readout)

d. salinity

Once the data have been collected, it should be summarized prior to statistical analyses to answer more specific questions. Such a summary should present the following information:

1. Station map - Labeled stations should be accurately plotted on a map that includes three depth contours, and a longitude and latitude scale on the boundaries.

2. Sample information table - This should include sample numbers on the right margin and sampling variables (e.g. locational, tow and gear) in columns.

3. Catch summarization table - This includes sample numbers in columns and biological and physical variables (at the sample level) in rows on the right margin. The following biological variables should be included for each sample: the total catch, total biomass, total number of species, and sample diversity (described below). In addition, survey characteristics should be summarized at the bottom including: total catch, average catch/haul, total biomass, average biomass/haul, total species (not additive), and average diversity/haul.

4. Catch information table - Each species is tabulated with corresponding abundance and number of individuals obtained in each sample noted. In addition, average abundance per sample for each species and a coefficient of dispersion (to measure degree of clumping) can be given. A similar table of biomass can also be presented.

5. Species lists - A list of the species, arranged taxonomically should be given. If common names exist (such as Bailey *et al.*, 1970, for fishes), these can be included here. In addition, lists of the most abundant and most common species can also be included.

6. Disease frequency tables - These present a species column and total number of individuals, number of diseased individuals and percent diseased, for each disease.

7. Variable maps - All sample variables can be plotted on maps of the stations. Hopps <u>et al</u>. (1969) gives methodology of plotting contours, shading maps, and symbol maps. In general, contour mapping should be done when variables are thought to form a continuous gradation from one place to another, whereas shading maps are more appropriate for variables that are relatively discontinuous (i.e., schools of fishes make abundances somewhat discontinuous). If shading maps are used, three or four divisions should be made, each division represented by a different shade. The range of values, divided by 4 (or 3) allows an unequal number of values to occur in each division, thus giving the reader some indication of the skewness of variable frequency distributions. Shading should grade from dark to light and high to low partition values (or low to high). "Symbol" maps have different sized symbols indicating different partition values (partitions can be determined in the above manner). These maps avoid estimating values for areas intermediate between the stations, although patterns are sometimes more difficult to visualize. Maps showing disease incidence should include the distribution of a given species in the survey in addition to a distribution of diseased individuals of that species.

8. Length frequency histograms or tables - Length frequencies of all species can be given for the survey as a whole and/or for each sample. If the data are presented graphically, the species are indicated on the vertical axis and size class (i.e. 10 mm intervals) on the horizontal. Otherwise, the number of individuals of each size class is tabulated for each species. The value of these graphs or tables increases when plotted against a line representing the known size range of each species, thus giving a perspective as to what portion of the population of each species is being captured. It should be

noted that the statistics giving average sizes are less meaningful here as size distribution histograms are often multimodal. The frequency of individuals in different size classes that are affected by disease can be plotted relative to the frequency of all individuals of that species to determine if the disease is size specific.

9. Physical, biological, and sample variables can be plotted against each other to describe correlations. Comparison of catch data with bottom water temperature and dissolved oxygen values may reveal seasonal effects or short-term anomalous conditions.

DIVERSITY

Most of the above variables can be directly measured or enumerated in the field. Measures of diversity, which may be indicative of environmental gradients, are generally calculated from formulas requiring two or more of the above variables, including: species, total abundance or biomass, and in some cases, abundance (or biomass) per species. The simplest measure of diversity (representing a variable) is merely the number of species in the sample (D = S). In many instances, the number of species in the sample is influenced by the number of individuals in the sample, and use of the Gleason Index ($D = \frac{S-1}{\ln N}$, a measure of species richness) gives a better representation of the diversity of the sample. However, since most of the catch in a given sample is usually distributed among a few of the species, information theory diversity analyses (i.e. Brillouin, $H = \frac{1}{N} \ln \frac{N!}{n_1!n_2!\ldots n_s!}$; Shannon-Weaver, $H' = -\sum_{i=1}^{j} \frac{ni}{N} \ln \frac{ni}{N}$, etc.) give a better description of the sample because the number of individuals per species is included in the calculation. By scaling these values to take into account differences in sample size (i.e. $\frac{H_{max} - H}{H_{max} - H_{min}}$; $\frac{H'_{max} - H'}{H'_{max} - H_{min}}$), a better description of the evenness of the distribution of individuals per species can be attained. Another measure of this evenness is the standard deviation diversity. Each of these indices essentially functions in analyses as a variable (although not measured directly in the field) and can be summarized in the same manner as a variable.

SUMMARY STATISTICS

Statistics used in the data summarization tables generally describe locational and dispersion characteristics of the frequency distributions of the variables. This generally includes measures of central tendency (i.e. mean, median, mode) or dispersion (i.e. ranges, standard deviations, standard errors). The manner in which these measures are expressed (i.e. mean vs. median) is determined by whether the criteria necessary in the assumptions for the use of each parameter are met. Parametric statistics (i.e. means, standard errors), which are those that are based upon a set of assumptions that include a normal frequency distribution, are most descriptive when used with variables that have frequency distributions which follow a normal curve. It has been our experience that the number of species per trawl sample approximates a normal curve and is adequately represented by parametric statistics without additional transformations.

Skewed unimodal curves frequently appear for biomass and number of organisms per sample and are not always adequately represented by parametric statistics without transformation. Various transformations have been used to account for Poisson, negative binomial and logarithmic distributions prior to applying parametric statistics and should be consulted (see Roessler 1965). Medians and non-parametric statistics were used by Mearns and Greene (1974) and appeared adequate to assess data from a synoptic trawl survey. However, transformation and use of parametric statistics can give a more detailed description of these kinds of data and should be used when possible. Other assumptions for parametric statistics and general statistical formulae can be found in most general statistical textbooks.

The Coefficient of Dispersion (variance to mean ratio) is a useful index of the distribution pattern of the species (i.e. CD = 1, pattern is random; CD > 1, pattern is clumped; CD < 1, pattern is even). This index can be applied to individual species over the whole survey. By including all samples (even those in which the species is not found) highly clumped species may be interpreted as occupying discrete habitat patches or aggregations. By only including samples in which the species is present, the interpretation is shifted toward aggregated or schooling species.

ANALYSIS AND REPORTING

Analyzing and reporting the results of a trawl survey should address the objectives of the survey as well as additional questions of basic importance. The investigator should direct some attention to the following:

1. Was the performance of the surveys affected by weather, sea state conditions, gear changes or other physical problems?

2. Do the data show any obvious geographical or depth-related gradients for the catch variables? What species account for these gradients? What physical factors relate to them?

3. Over time (seasons, etc.), what obvious changes or trends occur in the catch variables and what species account for them? Do disease and parasite infestation show seasonality?

4. When and where do juveniles of dominant species appear in the catches? Do these species appear to reside in the survey area or migrate in and out? Do they show obvious growth patterns? Are diseases species-specific or specific to certain size groups?

5. How do catch variables compare with data taken by other methods in past years or with trawl data from adjacent areas?

6. Was sampling sufficient to meet the objectives?

Variable values can be compared from two or more points in space or time (i.e. outfall vs. control stations, predischarge surveys vs. postdischarge surveys), by using t-tests or analysis of variance (or their nonparametric equivalents such as Mann-Whitney-U tests, Krushal-Wallis) to determine where significant differences exist.

In addition to the above analyses, a variety of clustering techniques can be used. These may be based on clustering similarity coefficients such as Sorenson's (1948). Clustering techniques fall into two basic types: site clustering and species clustering. Site clustering techniques form clusters of similar sites, based upon species composition and abundances (Stephenson *et al*. 1972). Species clustering techniques form clusters of species based upon frequency of joint occurrences (Fager 1957, 1963) or correlation (or some other similarity measure) of abundances. Both techniques are useful and have been combined by some authors (Stephenson *et al*. 1972). Both types generally begin by calculating an index of similarity between pairs of sites or species (e.g. Sorenson 1948) and applying a grouping technique (Stephenson *et al*. 1972). Groups can be presented in boxes (species or sites clustered above a given value of a similarity index) or in dendograms. Species groups often represent natural communities in nature, particularly if sampling has been over a very large area (e.g. Fager and Longhurst 1968; SCCWRP 1973), and changes in their structure or composition may be relatively more important to the ecology of an area than changes in other variables.

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16. ABSTRACT

Ecological surveys using small otter trawls provide useful and informative data on demersal fish and epibenthic macroinvertebrates of coastal soft bottom areas.

This report presents recommendations for selecting and using small otter trawls in coastal biological surveys and suggests methods for handling catches and processing data.

Use of small trawls in monitoring surveys is an adaptive use of their original purpose in commercial fishing. Many investigators have made effective use of small trawls in ecological surveys and some of this work is reviewed.

Nets ranging in headrope length from 10 to 16 feet are recommended for shallow waters, estuaries, lagoons and aboard small boats; 25-foot nets are recommended for open coastal areas.

Use of the gear, accessory gear and care and trouble-shooting procedures are described. Some aspects of survey design, data summarization and data analysis are reviewed.

17. KEY WORDS AND DOCUMENT ANALYSIS

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