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THE SUITABILITY OF SOME CURRENT FISH SAMPLING METHODS FOR MONITORING NUCLEAR POWER PLANTS WITH EXPECTED MINIMUM IMPACTS

by

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CONTENTS

ABSTRACT

Fish sampling methods from the monitoring programs at the proposed Kiket Island power plant and the San Onofre Nuclear Generating Station were examined for their ability to detect catastrophic population changes and their suitability for use in less intensive monitoring programs. The evaluations were based on:

1. the variance of the relative abundance estimates and the ability of the method to detect the expected seasonal changes,

2. the quality of the biological data, such as length-frequency distributions, which could be used as additional measures of change, and

3. the lag time between a change in the juvenile populations and its detection by the technique.

Six techniques could detect catastrophic changes in the species considered. Of these, the townet, beach survey, trynet, and gillnet were suitable for less intensive monitoring programs of various types. The acoustic survey and the otter trawl were considered unsuitable and were rejected along with the lampara net and the sport and commercial catch and effort statistics.

INTRODUCTION

In recent years there have been a number of intensive sampling programs at various nuclear power plants to try to monitor the plants' impact on the surrounding fish populations. In cases of high expected impact these programs are necessary and worthwhile. However, in cases of minimal expected impact, the effort and expense of intensive monitoring programs may not be justified.

This report examines a number of current fish sampling techniques for their ability to detect population change and their suitability for use in less intensive monitoring programs.

METHODS

Fish sampling methods from two studies were examined. The first was the University of Washington's 3-year Kiket Island project in North Skagit Bay, Washington, which was designed to study the potential impacts of a proposed nuclear power plant on (1) juvenile salmonids migrating from the Skagit River and (2) marine species diversity in Skagit Bay (Stober and Salo 1973). The second study, along the southern coast of California, was part of the required environmental monitoring program for the San Onofre Nuclear Generating Station (SONGS), (Southern California Edison, 1975, 1976, 1977) along with other supplemental programs (Thomas et al. unpublished). The techniques examined include townetting and beach surveys for juvenile salmonids, otter trawling and trynetting for marine species at Kiket Island, and gillnetting, acoustic survey, lampara netting, and sport and commercial catch data analysis for San Onofre.

For evaluating the various techniques, a theoretical monitoring program was established whose objective was to act as a flag for initiating a more intensive monitoring program if a catastrophic change ($\geq$50%) occurred in the surrounding fish populations. The program was not concerned with detecting small changes. Nor was it designed to determine near-field effects, since these were assumed to occur but to be small enough that the far-field populations were not affected. A previous baseline study was also assumed so the monitoring program was not concerned with developing complete species lists. In addition, because of the baseline study, it was assumed that target species or groups could be picked upon which to concentrate the monitoring.

Given this monitoring program, the three major concerns in the technique evaluation were:

1. The method's variability and its ability to detect large population changes within a species.
2. The additional information, such as length-frequency, which the method provided.
3. The lag-time until the change was detected by the techniques.

Because the fish populations changed with time, means, standard deviations, coefficients of variation, and confidence intervals were calculated for measurements within individual survey periods. For the townets, beach surveys, and trynets, these were daily periods. Gillnet data were also computed daily, but the control and discharge areas were considered separately. Acoustic variability was computed for each survey period of two to four days. Because there were not enough replicates to compute otter trawl variability on a daily basis, the results of the fourteen bimonthly surveys were combined and variability was computed by station.

Since each sample in a period was assumed to be from the same normally distributed population, the .95 confidence intervals for selected periods of each technique were constructed with the t-statistic. The percentage of confidence intervals with lower boundaries at or below 0.0 (points at which no decrease can be proven statistically) was then tabulated by gear and presented in Table 1 along with the ranges for means, standard deviations, and coefficients of variation.

Time limitations and the complexity of the marine environment precluded the analysis of each species' catch by every gear, so two species were selected from each type of study to examine in detail. These included pink (Oncorhynchus gorbuscha) and chum salmon (Oncorhynchus keta) for the Kiket Island juvenile salmonids program, English sole (Parophrys vetulus) and Pacific tomcod (Microgadus proximus) for the Kiket Island marine diversity study, and queenfish (Seriphus politus) and white croaker (Genyonemus lineatus) for the San Onofre monitoring program.

Generally, these species were picked because they were among the most numerous at the site and therefore had the most data. At least three of the species had some commercial interest (pink and chum salmon, English sole), and because of their large numbers, each species was assumed to be important in the local system. Other species such as the northern anchovy (Engraulis mordax) were more abundant than the selected species at various times, however, their unpredictable migration patterns precluded any local analysis of population change.

RESULTS AND DISCUSSION

Kiket Island - Juvenile Salmonids

Since Kiket Island was developed as a research project, a number of methods were used to monitor salmonid populations and migration routes. Most of these were variations on a trawl-type townet and included 5- and 10-min surface tows over more-or-less set courses, 10-min midwater tows at 0, 30, and 60 ft in fixed locations, and night tows for each of the above (Stober and Salo 1973).

The net, which was towed by two boats, had a 10-ft x 20-ft opening and was 43 ft long, with graduated panels of mesh from 3 inches at the leading edge to .25 inches in the cod end (Stober and Salo 1970). It was usually towed for 10 min and then brought on board and emptied in the usual manner. However, for the 5-min tows, the net was emptied by an additional man in a skiff over the cod end. This was more expensive, but it was faster because the net did not have to be retrieved each time and a more-or-less continuous course could be followed.

The primary advantage of the net is that it obtains quantitative estimates of small fish which would pass through a larger mesh net, yet the net is large enough that gear escapement and avoidance are much less than with the smaller plankton-type nets. Also, the technique is fast enough that many samples can be taken, increasing the power of the technique.

The major disadvantage of the townet is that it must be used in open water. It is unsuitable for sampling the shallow, uneven, or stump-strewn shorelines where many species of young fish are found. The net is also unsuitable for sampling larger fish because the problems of gear avoidance and escapement become severe.

Although all townet methods showed the expected yearly migrations of the pink and chum juveniles - starting in late March, peaking in late April or early May with the increase in river discharge, and dropping to almost zero by June (Fig. 1) - and each also picked up the large natural fluctuations in pinks and chums between years, the 5-min daytime surface tow was the most suitable for monitoring the populations of juvenile pink and chum salmon in the open areas of Skagit Bay. The catch/tow was fairly large, as was the variability (Table 1), but the large numbers of samples (approx. 50 per day) increased the power of the technique and brought the .95 confidence limits into a workable range.

The 10-min tows had a slightly lesser variability (Table 1) which was probably due to averaging the heterogeneous fish distribution over a 10-min span instead of just 5 min, but the lesser number of samples decreased the power and increased the confidence intervals. This difference was obvious when the .95 confidence intervals were compared for the two methods. Of the eight periods in 1971 and 1972 for which intervals were computed, only 2 (25%) of the 5-min intervals included zero while seven (87.5%) of the 10-min tow intervals did so. With such a large portion of the intervals including zero, it was unlikely that any population decrease, even a major one, could have been detected by the 10-min tows.

The 5-min tows in 1970 also had a high proportion (75%) of confidence intervals containing zero, however, the mean catch/tow was also much smaller than in 1971 and 1972, so this was expected. Under such conditions of low density, sampling effort could be increased to further reduce the confidence intervals. Fortunately, gross differences in townet catches seem to be predictable from the adult escapement data for the Skagit River (Ames, personal communication) for the previous year so that sampling effort can be planned in advance. However, just three years of data (two for pinks, one for chum) is not conclusive in this respect.

The midwater tows were unsuitable for monitoring population change in juvenile salmonids because at least 90% of the fish were taken at the surface when 0-, 30-, and 60-ft depths were sampled. This gave extremely small catch/tow values at 30- and 60-ft so that population decreases could not have been detected by those tows. The surface midwater tows were slightly less variable than the regular 10-min tows because of the fixed, similar sample sites. However, the decreased variability was not worth the decreased confidence that the entire population was being sampled. If only the three fixed locations were sampled, a change in migration patterns or in the local populations could have lead to the conclusion of a drastic change when none had occurred.

The night tows generally gave slightly smaller catches and coefficients of variation. However, the tows were unnecessary because the differences in the coefficients of variation were small (.05), inconsistent, and not worth the additional salaries necessary for overtime work.

In addition to the townets which measured offshore abundance, a beach survey was used to get semiqualitative estimates of juveniles along the shoreline. This consisted of walking the shoreline or cruising it in a small boat and estimating the numbers of juveniles seen in each quarter-of-a-mile section (Stober and Salo, 1970).

There are a number of problems with the beach survey, particularly the effects of wind, weather, and time of day on visibility. There are also problems with fish avoidance, and with estimating the number of fish in a school if there are too many to count or if the whole school cannot be seen.

On the other hand, the beach survey is about the only method of population estimation along a rocky, obstructed, or steeply sloping shoreline. Beach seines can be used, but they need a fairly shallow, uniform bottom to be effective so they are limited to a smaller number of sampling sites. This reduces the power of the beach seine and gives less confidence that the true populations are being sampled.

Even with its semi-quantitative results, the beach survey was necessary for the Kiket Island monitoring program because the majority of juvenile pink salmon stayed along shore and remained unavailable to the townets as they migrated out of the bay (Stober and Salo 1971). This would not have been a problem except the townet catch and beach survey results for pinks were totally unrelated, and using just one method could have seriously misrepresented their abundance. This was not the case for juvenile chum salmon because they moved into the open water and became available to the townet before they left the bay (Stober and Salo 1971). Therefore, their beach survey numbers and townet results reflected the same direction of population change.

Other studies have tended to show similar correlations between townets, beach surveys, and beach seines for both chum and pink salmon (Bax et al. 1978; Schreiner 1977). However, these studies have concentrated the townetting along the shorelines instead of covering the inshore and offshore areas equally as in the Kiket Island study.

Kiket Island - Marine Species

Two gears, the otter trawl and the trynet, were used to sample demersal fishes in Skagit Bay (Stober and Salo 1973). The gears were similar in that they were both designed to be towed along the bottom by a single boat, however, they were designed to fish different areas and to capture different fish. The trynet was designed to capture small fish in relatively shallow water. The otter trawl fishes deeper and generally catches larger fish.

The major differences between the gear were in the size of the net, the size of the cod end mesh, and the speed of the tow. The otter trawl had a 10-ft x 20-ft opening, a 1.5-inch cod end mesh, and it was towed at about six knots. The trynet was smaller, with a 3-ft x 10-ft opening and a .25-inch cod end mesh. It was towed at about 3 knots.

The areas sampled by the gears were also different. The otter trawl sampled three mid-bay areas, two of which were about 90 ft deep and one which was 18 ft deep. The trynet sampled three nearshore shelf areas with an average depth of about 20 ft.

Since the two gears are similar, they have many of the same disadvantages and limitations. They do not work well over very rugged or obstructed bottoms, and they cannot work the shorelines. Since both methods can capture large numbers of fish, there is also the possibility of creating a sampling impact if the gears are used extensively in relatively small areas. Finally, there are many problems with the changing catchability of a species and selectivity by the net. Illumination, water clarity, and the size, shape, and speed of the trawl directly influence catchability (Chestnoi 1968; Martyshevski and Karatkan 1968). There is even some evidence that catchability is affected by the density of fish in that increasing density may disperse more fish into the upper layers and make them unavailable to the trawl (Ulltang 1977).

Selectivity is also very important with these gears. The habitat, size, shape, and swimming speed of the fish determine what enters the net and cod end mesh size determines what is retained. Generally, the most vulnerable species are the slow, semidemersal fishes which live right above the bottom. True demersal species, such as flatfish, are somewhat less vulnerable because they can burrow into the mud and let the trawl pass over them. In one study, only 13% of the flatfish population was picked up by an otter trawl during the day (Christensen 1967). This percentage can be increased considerably by trawling at night when the flatfish are up and moving around.

In terms of the Kiket Island data for English sole and tomcod, both methods picked up large variations in abundance (CPUE) within years. Most of these changes were cyclic as in tomcod catches/10-min trawl (Fig 2). This was expected since both English sole and tomcod are known to migrate from deeper water in winter to shallower water in the spring (Ketchen 1956;

Hart 1973; Saetersdal 1967). However, the timing of the cycles varied between the otter trawls and the trynets, as well as between the two deep otter trawl stations (90 ft) and the shallow site (18 ft). This discrepancy was probably due to differences in temperature and salinity between depths. The same reasoning can be used to explain the similarity between the shallow otter trawl station (18 ft) and the trynet results (20 ft).

Age composition also tended to be cyclic and related to depth, especially for the English sole. Again, this was expected since English sole have been shown to move further offshore as they grow older (Clemens and Welby 1961). If you assumed that all sizes migrated an equal distance offshore in the winter, the observed cycle of small fish in winter and larger fish in the summer could be explained. But even so, it was impossible to use length-frequency data from the trawls to follow a given year class of English sole from period to period or from year to year.

Although it was not tested, there seemed to be a correlation between age structure and CPUE for English sole from the otter trawl because the highest catches were during winter when the length-frequency was skewed to the left, and the catch was smallest in June and August when the larger fish were present. However, there were enough fluctuations and unexplained dips in the CPUE that the relationship is still unconvincing.

Too few trynetting periods with large enough samples sizes to construct length-frequency diagrams were available to draw any strong conclusions, but the English sole data seemed to follow the same pattern as for the otter trawl.

Age composition for tomcod did not show a strong cyclic pattern, nor were there strong indications that the length-frequencies changed significantly with depth, even though CPUE did (Fig 2). However, the length-frequency was sufficiently variable between periods that it was impossible to follow any but a very large year class. Because of this, a single disasterous spawning season might not be visible, but a recurring problem would show up rather quickly.

Since the smaller and therefore younger fish are generally found in shallow nearshore areas, the trynet is the better of the two gears to use in a monitoring program for English sole and tomcod. Changes in the overall population size will be reflected in the juvenile populations either by increased mortality rates or decreased birth rates, and the younger the fish are sampled, the smaller the time-lag between impact, detection and corrective action.

However, because of the small catch/tow values and the fairly large variance of the trynet, more samples per day or longer tows must be taken to bring the confidence intervals above zero.

San Onofre - Marine Species

The San Onofre monitoring program was somewhat different from the Kiket Island project in that it was developed strictly to monitor power plant effects on fish and not as a research project. It was also along the open coastline instead of in an enclosed area as was Kiket Island.

Four monitoring techniques were used at the San Onofre site: gillnetting, acoustic survey, lampara netting, and analysis of sport and commercial catch and effort data.

The gillnet survey, which was performed to satisfy ETS requirements, consisted of quarterly sets of twelve 150-ft experimental gillnets. Two fixed stations were sampled: one near the SONGS discharge and a control about four miles southeast of the plant. After an initial period of experimentation to see which substrates and depths produced the best catches, the nets were oriented perpendicular to shore and set on the bottom over a cobble substrate in 9 m of water (Southern Calif. Edison 1975a).

The gillnet's greatest advantage was that it sampled pelagic and highly mobile demersal species for a minimum cost. It also gave a fairly low variability because the 24-hr sets tended to average out the patchy distributions and activity periods of the fish. The 24-hr sets also gave catches per net which were large enough to allow reasonable, non-zero confidence intervals from a small number of nets, especially for Seriphus (Table 1).

The primary disadvantage of the gillnet is its high selectivity for species and size. This can be somewhat reduced by using experimental gill-nets with their panels of different sized mesh; however, some selectivity will always exist and it must be considered for abundance estimates and length-frequency distributions. Fortunately, this is not a serious problem in a monitoring program for catastrophic change because the exact magnitude of the change is unimportant.

Other limitations of the gillnet are its high selectivity against non-motile bottom fish, such as some flatfish, and its tendency toward gear saturation and reduced fishing ability. The net also samples an unknown area so absolute abundance estimates are not possible.

Although the catch per net for Seriphus in the control area varied considerably over a year, it followed the expected migration pattern very well (Skogsberg 1939) (Fig 3). The variability and the confidence intervals for the sampling periods were also fairly small so that a large change should have been observed had it occurred at the sampling sites (Table 1).

However, since the control sampling site was a single fixed location, there is at least a reasonable possibility that a large change occurred, but that it was not great enough in that particular location to be noticed. Conversely, a local change might have occurred around the sampling site due to changes in migration routes or feeding habits and it would have been interpreted as a major population change for the entire region.

The obvious way to avoid this problem is to spread the sample sites out over a larger area. The different stations should increase the variability within periods slightly, but as long as all of the stations are at the same depth and over the same substrate, the increased variability should be worth the increased confidence in the technique.

The catch/net for *Genyonemus* in the control area was much less variable than for *Seriphus*. Again, this follows the expected pattern since no pronounced seasonal migrations have been reported for this species. However, the catch/tow is much lower than for *Seriphus*, and a number (33%) of the .95 confidence intervals include zero, so a population decrease would be harder to detect.

Neither the catch/net for *Seriphus* nor *Genyonemus* followed the expected pattern in the discharge areas, but this was probably due to near-field plant effects. Since the proposed monitoring program assumes a near-field effect and is only concerned with far-field impacts, this will not be discussed further.

The sample size of *Seriphus* and *Genyonemus* in each period was generally too small to draw any conclusions on length-frequency. However, in each plot of *Seriphus* there was a large group of fish around 135 mm which was about 2 years old. If there was a poor year class of *Seriphus*, it should become obvious by the second year when they become recruitable by the gillnets.

A series of seven acoustic surveys was conducted between September 1976 and June 1977 to determine the effect of a SONGS shutdown and resumption on the surrounding fish populations (Thomas et al. 1978). Each survey, which lasted about four days, measured the fish density along a number of transects in the vicinity of the plant. These transects were changed slightly between periods, but in general they included 3-mile transects along the 5-, 7-, 10-, and 20-meter isobaths as well as transects perpendicular to shore near the SONGS discharge. During three of the surveys, lampara net samples were taken to provide species composition of the acoustic targets.

Briefly, the acoustic system consisted of a transducer and a receiver which sent and received the sound signals, a strip chart recorder which gave a visual record of the targets, and an interface amplifier and magnetic tape recorder which stored the data for later analysis by a computerized echo integration system to give average fish density at 1-min intervals along each transect.

The great advantage of acoustics is that it gives an exact, continuous record of what is in the water column at that time. It is also fast and is non-destructive, so that extremely large sample sizes can be obtained without affecting the fish population. This tends to give great power to the results.

The greatest disadvantage of the method is that it measures only biomass present. It cannot give species composition, length-frequency distribution, or age and growth data because the fish are not captured. Consequently, a large portion of the acoustic analysis must depend on the results from other techniques, such as lampara netting which may or may not be accurate.

Another disadvantage of acoustics is that it can only measure what is in the water column; the method is inefficient for benthic species such as flatfish which may lie on or under the bottom. This problem can be reduced somewhat by adjusting the sensitivity of the receiver and by sampling at night when the fish are more active and more likely to be off the bottom, but the results for benthic species are still variable and uncertain.

Tape saturation or shadowing of underlying fish by dense schools in the upper layers also causes occasional problems in acoustic work, but these are easily corrected by adjusting the sensitivity of the unit. However, if the sensitivity is adjusted for large, dense schools, the biomass estimates may be low, because many of the small scattered individuals would probably be missed.

Finally, because they are quicker than other methods, acoustic surveys are relatively inexpensive on a cost/volume sampled basis. However, the large initial investment for the echo integration system and the need for an auxiliary method to produce biological data tend to make acoustic work very expensive.

Since both *Seriphus* and *Genyonemus* are usually found above the bottom, and since they both tend to form small schools (Skogsberg 1939) during the day when most sampling was conducted, the acoustic monitoring should have been effective. This seems to be the case because the acoustic results support both the gillnet data and the lampara data which suggest population decreases during winter (September-March) and increases in the spring (June). This comparison is not exactly correct because the species composition at the site changed over the course of the survey (Thomas et al. 1978). However, that too indicated an increase in *Seriphus* and *Genyonemus* from February to June.

The acoustic results also supported the gillnet observations of greater fish density over cobble (hard) substrate than over soft substrate.

Even with the great power and continuity of the acoustic data, this method is generally unsuitable for a monitoring program such as considered in this report. The lack of species identification or other biological data force estimates of change to be based on density only. This might work well in a system with only a few species, but in more complex systems, such as San Onofre, a drastic population decrease in one species could easily be masked by population changes in other resident fish or by influxes of migrant species.

Rather than being used to detect an effect, the acoustic survey seems to be more useful as an auxiliary technique to explain observed effects. It is especially good for impacts, such as temperature, which are related to distance because the survey gives a continuous record over each transect. This continuity is not needed in a far-field monitoring program which is geared soley towards detecting large population changes.

Lampara netting was used to sample species composition during three of the acoustic survey periods. The method was very similar to purse seining in that a long, high net was deployed in a circle around a random area or a school of fish. As the net was retrieved, the ends or wings of the net pulled together and trapped the fish in the bag of the net.

The advantages of the lampara net are that it can catch swift pelagic species which would outrun or avoid most other gears and it can capture specific schools of fish. Once an area is encircled, the method is also pretty much non-selective except for fish small enough to pass through the meshes of the net. However, very strong biases can be introduced if the net is aimed because schooling fishes may become more selected than scarce, non-schooling ones. Also, size and age biases may be introduced because fishes of similar size tend to school together. Aiming the net can also cause erroneous population estimates which change with the size of the schools captured.

On the other hand, the net sets must be aimed at fish by sight or by acoustics or they are very inefficient, because a large percentage of the sets come up empty.

Too few periods were sampled to determine the effectiveness of the nets in following population and age composition changes. However, the catch data for Seriphus and Genyonemus tended to support the gillnet conclusions of an increase in the populations from February to June.

There were two obvious differences from the length-frequency distributions of the gillnets. First, the January-February lampara nets picked up smaller Seriphus than the gillnets - down to about 40 mm instead of the 100 mm for gillnets. This was probably related to differences in minimum mesh size. The second difference was that the lampara nets did not seem to pick up any of the larger specimens of either Seriphus or Genyonemus. This might have been due to some near-field effect which drove off the larger fish, but it was more likely caused by selection of schools of smaller fish.

This method is unsuitable for a monitoring program because the aiming necessary to make the technique effective would tend to bias the species composition and relative abundance estimates, and fishing only certain schools would bias the observed length-frequency distributions.

Sport and commercial catch and effort data from the California Department of Fish and Game was also used to monitor fish populations at the San

Onofre site (Southern Calif. Edison 1975b, 1976, 1977). This method was inexpensive because no field work had to be done, but it was also ineffective for monitoring population changes in *Seriphus* and *Genyonemus*.

The largest problem was that neither of the fishes was a sport or commercial species, so no valid catch or effort data was collected. Values were available, but they were probably much too low because of released or uncounted fish. Any estimate of effort was inappropriate because queenfish and white croaker were not the target species.

Even if the fishes had been sport or commercial species, the data would not have been effective in determining population change because the changes in fishing gears, regulations and in the effort directed toward a particular species would have made evaluation very difficult. The large blocks for which the statistics were compiled (10 mi x 10 mi) would also have tended to mask even a significant effect from SONGS because of the relatively small area involved.

Finally, the compilation of the data is very time consuming, so it may take many years before the statistics are available. This is an unacceptable lag for a monitoring program, especially when it is added to the lag between juveniles and recruitment by the fishery.

The commercial and sport statistics for San Onofre were not comparable to the other methods because there was a two-year-lag in compiling them. The catch-effort data was for 1973-1975, while the other methods were used at varying times from 1975-1977.

SUMMARY AND CONCLUSIONS

1. Of the sampling techniques for juvenile salmonids used in the Kiket Island study, the 5 min daylight surface townet was the most useful for detecting population changes of pink and chum salmon in open water. The other townet techniques were rejected because of high variance, low catch/tow, or cost.

2. Beach surveys, although only semi-quantitative, were necessary for the salmonid monitoring program because of the large numbers of fish inshore and the lack of a strong correlation between townet and beach survey results. This was especially true for pink salmon because they tended to stay along the shore as they migrated from the bay.

3. Both the otter trawl and the trynet were effective for monitoring the seasonal changes in abundance for English sole and tomcod, so either method should be able to detect a catastrophic change. However, the trynet is more suitable for this type of monitoring program because it generally samples shallower areas and catches younger fish, so the time lag between the population change and its detection should be less for the trynet than for the otter trawl.

4. Length-frequency data for English sole and tomcod were too variable to follow individual year classes from year to year. However, a series of weak or unsuccessful spawnings should be detectable as the year classes become recruitable by the trawls.

5. Although they were selective for size and species, the gillnets were effective in monitoring the seasonal abundance changes of queenfish and white croaker. They also detected the expected seasonal changes in length-frequency for the queenfish, but individual year classes could not be followed from season to season or year to year.

6. The acoustic surveys provided very powerful estimates of fish biomass in the San Onofre area, but the technique is unsuitable for non-intensive monitoring programs because it cannot give species composition or other biological data and it must rely on other techniques such as lampara netting.

7. The lampara net is also unsuitable for a monitoring program of this type because the aiming of the sets, which is necessary for efficient sampling, tends to bias species composition, length-frequency distributions, and relative abundance estimates.

8. Sport and commercial catch and effort data from San Onofre were invalid for queenfish and white croaker because they were not sport or commercial fish. However, the statistics would also be unsuitable for monitoring populations of commercial or game fish because of the large size of the statistical areas and the long lag time for compiling the data.

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Table 1. Summary of gear variability.

Gear		Range of period Means		Range of period Standard deviations	Range of period Coefficients of variation	% Confidence intervals containing 0.0
Townet	5 min	1.05-73.85	fish/tow	3.26-127.27	1.61-5.73	25
	10 min	.20-103.04	fish/tow	1.29-222.67	1.94-4.01	87.5
Beach survey		18.94-27190.44	fish/1/4 mi	27.00-32109.91	.60-1.98	38
Trynet	English sole	.00	fish/tow	.41-11.93	.08-2.44	66
	Tomcod	.00-12.75	fish/tow	.50-13.52	.87-2.20	100
Otter trawl	English sole	30.17-390.25	fish/trawl	20.11-436.91	.67-1.23	0
	Tomcod	257.58-406.91	fish/trawl	197.95-614.23	.77-1.73	33
Gillnet	Seriphus	.17-76.33	fish/net	.52-54.97	.19-1.16	0
	Genyonemus	.00-61.25	fish/net	.51-48.70	.13-1.75	33
Acoustic		1.58-9.60	g/m^2	5.72-32.88	3.43-6.94	0
Lampara	Seriphus	48.00-137.39	fish/set	83.75-157.14	1.14-1.74	0
	Genyonemus	13.69-49.67	fish/set	20.20-95.69	1.47-1.93	0

Table 2. Summary of sampling methods.

Method	Advantages	Disadvantages	Applicability
Townet	Gives quantitative estimates of abundance Fast enough that many replicates can be taken	High escapement and avoidance by larger fish Limited to open water	Samples juvenile fish populations in open water
Beach survey	Can sample rocky, obstructed, or irregular shorelines Many replicates possible	Semi-qualitative Depends on good weather conditions Poor species differentiation	Estimates juvenile populations along shorelines
Otter trawl	Quantitative technique Generally gives large sample sizes	Many problems with selectivity and changing catchability of fish Generally poor for pelagic fishes	Samples benthic species in deep areas with fairly uniform bottoms
Trynet	Quantitative technique Generally catches smaller fish	Many problems with selectivity and changing catchability of fish High escapement and avoidance by larger fishes	Samples small benthic fish in relatively shallow water
Gillnet	Relatively inexpensive low variability with 24 hr sets Can sample pelagic fishes	High selectivity for species and size Does not sample non-motile fishes Samples unknown area	Samples most motile fishes in fairly shallow areas

Table 2. Summary of sampling methods (cont'd.).

Method	Advantages	Disadvantages	Applicability
Acoustic survey	Gives continuous record of fish biomass throughout transects Very powerful because of large sample size	Does not give species composition or other biological data Normally poor for bottom fishes Relatively expensive	Monitors biomass change with distance for pelagic and semi-demersal fishes
Lampara net	Can capture swift pelagic species Can capture specific schools Net is relatively non-selective	Sets must be aimed to be efficient Aiming may create strong biases in species composition, length-frequency, and relative abundance estimates	Samples species composition and age distribution of selected fish schools
Sport and commercial catch and effort data	Inexpensive because no field work is involved Gives large sample sizes Gives overall picture instead of just local changes Can monitor migratory species	Only good for sport or commercial fish Changes in gear, regulations, and effort make analysis difficult Large statistical blocks mask local changes Long lag time before statistics are compiled and released	Monitors population changes in sport or commercial fishes

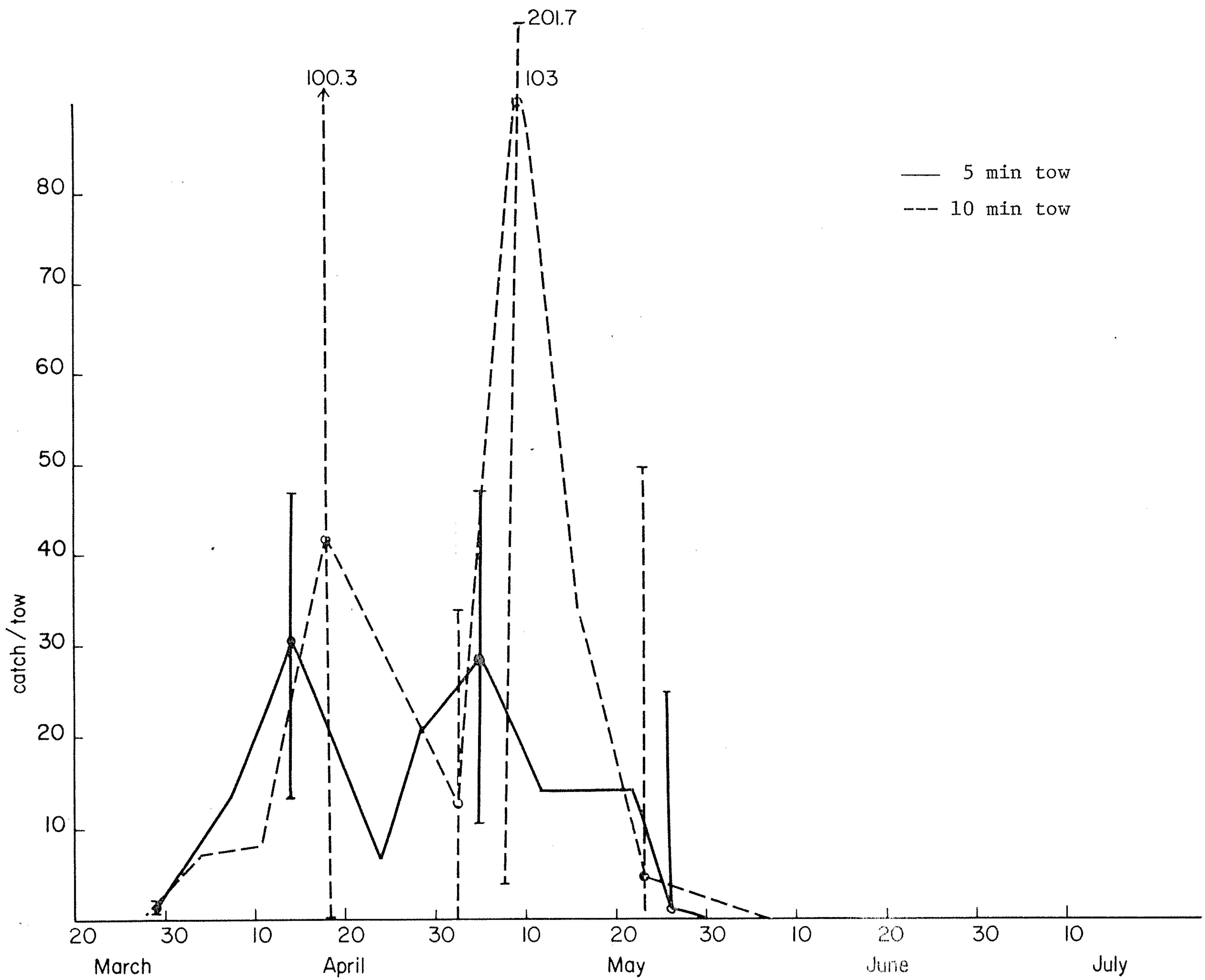

Figure I. Mean catch /tow and selected confidence intervals for pink salmon in 1972 5 min. and 10 min. townets.

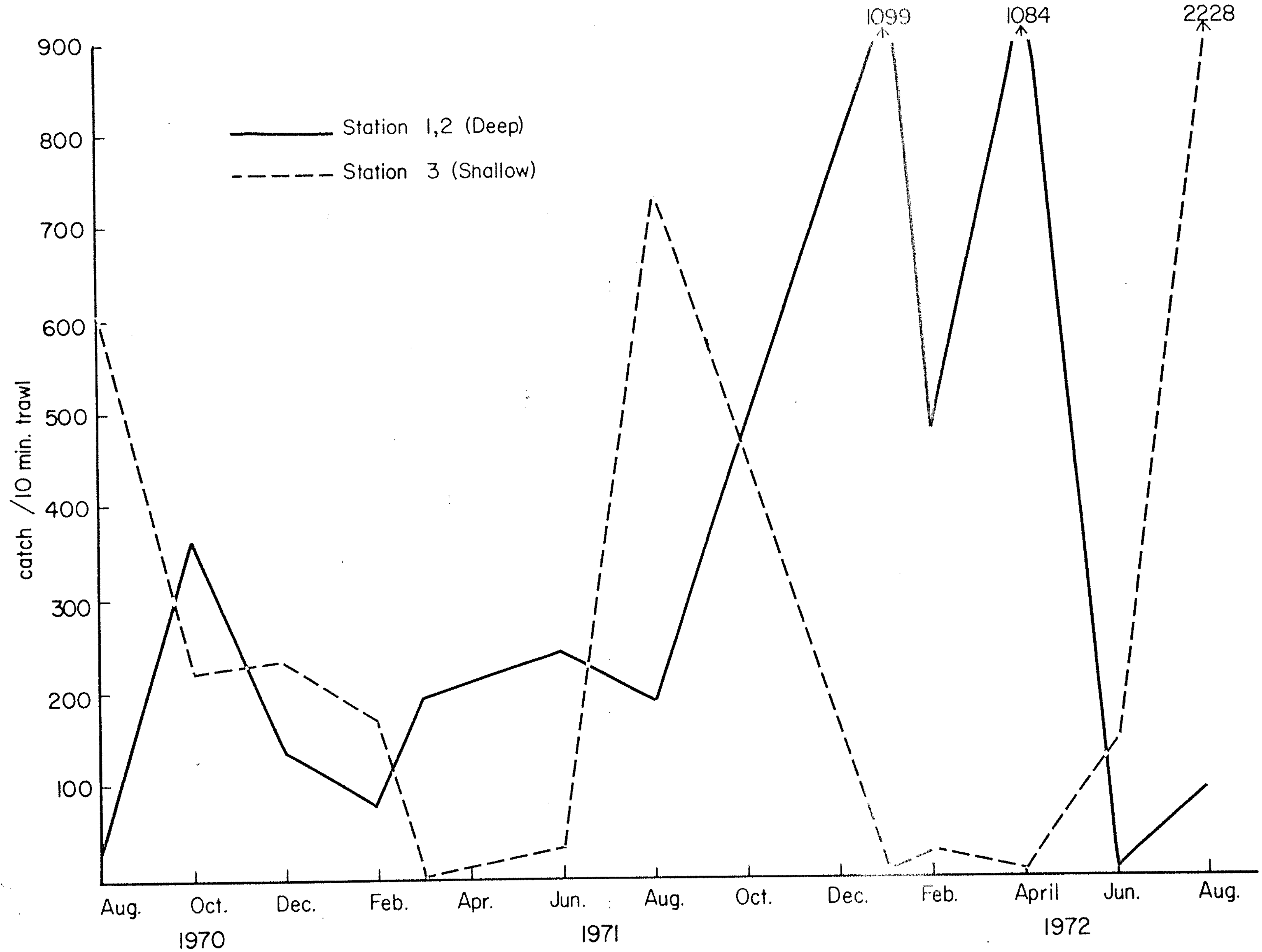

Figure 2. Tomcod catch /10 min. Otter trawl.

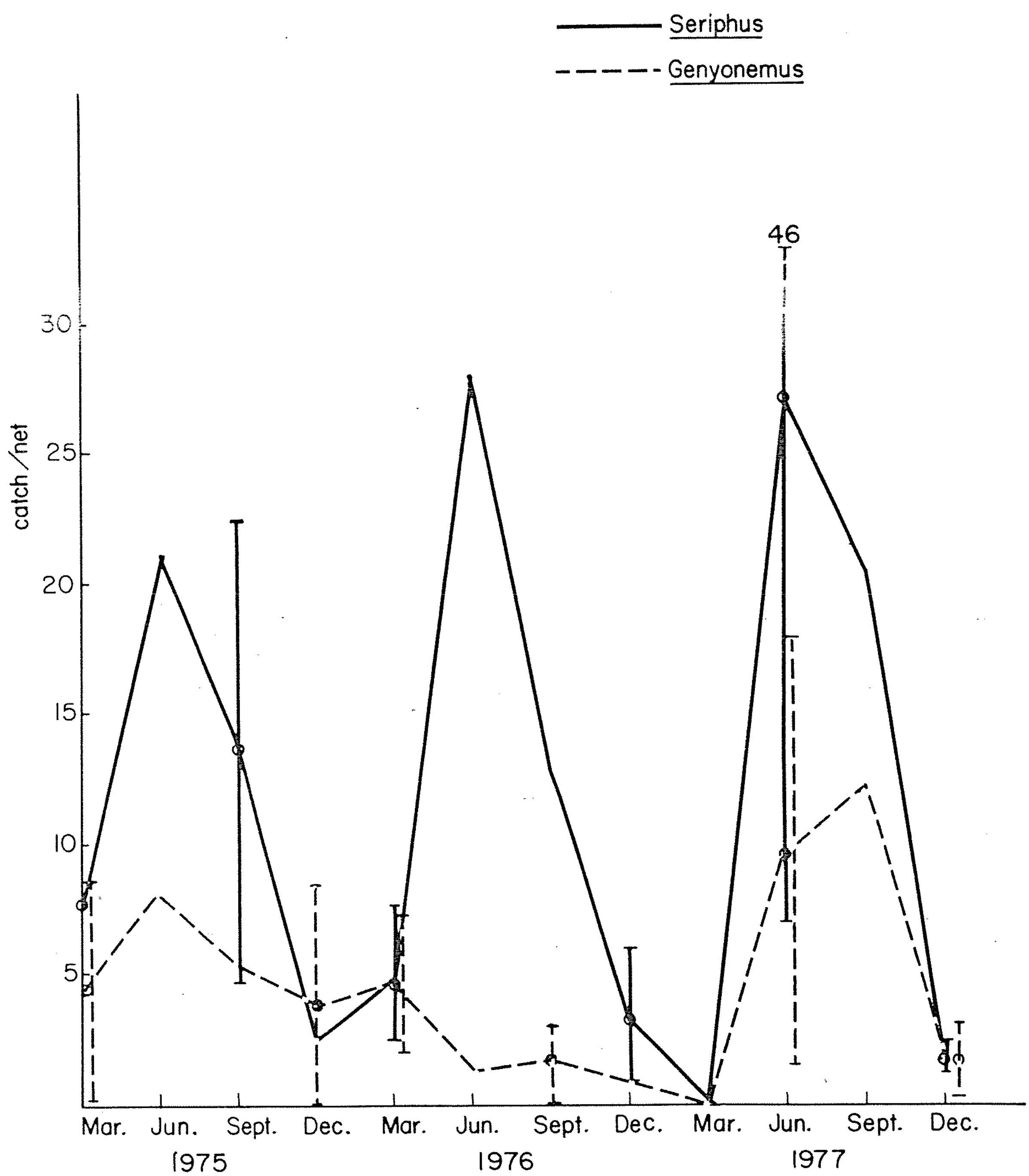

Figure 3. Mean gillnet catches and selected confidence intervals for Seriphus and Genyonemus.