A Protocol for Designing a Sea Survey for Anchovy Biomass Assessment

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ABSTRACT

The objective of obtaining a representative sample of the adult northern anchovy population, for the purposes of determining reproductive status, is discussed. Several considerations affecting this objective are listed, including deterioration of tissue, vulnerability to sampling gear, geographic variability in reproductive behavior, logistic limitations, and secondary indicators of the presence of fish. The timing and duration of a survey, the laboratory equipment required, and potential problems are discussed. Specific specifications for a desired survey vessel are also outlined including sea day capability, gear operations, vessel speed, personnel, storage, work space, and cruise plan.

SEA SURVEY DESIGN AND METHODS

Collection Gear Requirements

The primary requirement for trawl collection gear is that it provides a representative sample of the adult anchovy population. Because it is the average fish that is of interest, rather than the average location, sampling density should parallel the density of fish. Thus, relatively fewer samples need be taken in sparsely populated waters near the edge of the range; however, these areas must be covered sufficiently well to confirm the extent of the range. Adult sampling should coincide as much as possible with the time and area of egg samples. Several considerations make this requirement difficult to achieve. These considerations include:

1) Fish must be preserved in a fresh condition so that histological criteria may be used to determine their reproductive status. The Southwest Fisheries Center currently requires that tissue be fixed within an hour of being caught, and this appears to be adequate. (Adult surveys conducted with a purse seiner off Peru extended this period to 2 h without adverse consequences; J. Alheit[2].) Because it is not possible to determine when a fish was captured, trawls must be of short duration so as to set and retrieve the net, subsample the catch, expose the gonads, and preserve the fish within the specified time period. The same must be required of alternative sampling gears such as purse seine or lampara nets.

2) Some portions of the adult population may be more vulnerable to capture than others; catches may vary with sampling gears, with time of day, and with reproductive status. In 1981, actively spawning female *Engraulis mordax* were oversampled with a trawl relative to females which had spawned the day before; purse seine catches, paired with the trawls, yielded equal proportions of active and postactive spawners. The sex ratio, determined from the trawl sample, was biased (towards males) only during the hours of spawning whereas the purse seine selectively caught females regardless of the time of day. The 1982 trawl survey caught equal proportions of active and postactive spawners although the sex ratio changed during the hours of spawning favoring the males (Picquelle and Hewitt, 1983). In contrast, a 1981 purse seine sample of Peruvian anchovy, *Engraulis ringens*, obtained off Peru oversampled actively spawning females as well as showed a diurnal pattern in the sex ratio of caught fish (Alheit et al., 1984). Furthermore, a comparison of the distribution of actively spawning females with a binomial distribution suggested that the fish were not independently distributed in the collections; fish which had spawned the day before appeared to be independently distributed. It was concluded from these observations that males and actively spawning females segregate out from other females during the peak hours of spawning at a depth (or an area) where they are more vulnerable to the trawl (Alheit et al., 1984). This behavior appears to begin early in the day before the ovaries hydrate and ends a few hours after spawning.

Bias due to gear selectivity, temporal or geographic distribution, or fish behavior should be watched for. Because it is not always evident, every set of adult collections should be checked for possible bias. Sampling gears and procedures should be modified so as to minimize potential bias. The ideal sampler is one that is invisible to the fish, to preclude avoidance, and one that samples through the entire vertical range of their distribution. If the source of bias cannot be eliminated, it may be corrected by use of appropriate availability factors and/or statistical stratification. If size of fish

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follows an oceanographic or geographic pattern, the samples must cover the range. For fishes which spawn very locally in time or space, representative sampling may be difficult, while for widely distributed spawners representative sampling may not be difficult to achieve. 3) Spawning may occur in areas where it is difficult to sample the adults. These include the nearshore and other shallow water zones where there is not sufficient depth to fish a trawl or set a purse seine net. *Engraulis mordax* spawns in the nearshore zone with the same intensity as observed throughout its habitat (Hewitt and Brewer, 1983); however, the reproductive output of adults in this zone must be inferred because of the difficulty in sampling there. It may be necessary to choose a sampling gear, which can be deployed in shallow or obstructed areas (such as a lampara net), for those populations that deposit a large portion of their spawn in shallow waters. 4) Time and personnel requirements must also be considered when selecting a sampling gear. As mentioned above, a gear should be eliminated if it cannot be set, retrieved, and the catch preserved in less than a specified time period. The vessels available and their speed of travel between stations may be determined by the choice of sampling gear. In general, a purse seine requires more people to deploy than does a trawl; however, there may be considerable variation between boats. One to two people are required to subsample and preserve the catch in addition to the personnel necessary to fish the gear.

Secondary information may be useful for improving sampling efficiency, but care must be taken not to cause unrepresentative sampling. For example, presence of eggs in the plankton tows indicates presence of fish, but absence of eggs does not imply absence of fish. Adult samples from areas of low spawning rates may be very important in obtaining a good biomass estimate. Secondary information may improve trawl success rates. Such information may include signs of fish encountered during recent survey operations, signs of predators, and results of other observers such as the fishery, airplane pilots, or other concurrent research cruises. If fish behavior is known, oceanographic information on water temperature, clarity, etc., may provide useful clues to presence and absence of fish.

It is highly recommended that adult collections be examined for evidence of avoidance and selectivity. In this regard, it is a good practice to sample the catch for age composition. This information may be used as additional criteria to compare gears, geographic areas, and time of day.

SURVEY TIMING AND DURATION

The timing of the survey should be based on biological information. The survey should be conducted during peak spawning activity of the adults. The number of samples required to estimate the spawning fraction increases exponentially as that fraction decreases (P. E. Smith[3]) so that the additional cost of sampling outside the spawning season rapidly becomes unacceptable. It is absolutely necessary that adult sampling be conducted simultaneously with egg sampling, either on the same vessel or on different vessels working in the same vicinity.

The duration of the survey depends on logistical considerations. These include area of the survey, desired sampling intensity, distance between stations and speed of the vessel, and fraction of the day available to conduct adult sampling. If more than one vessel is available, sampling may be conducted 24 hours/day, which would allow more stations to be occupied in the same amount of time. However, the fish may be less catchable during daylight hours, either because they are deeper or because they can better avoid the net. As with the choice of gear, a compromise must be made between quantity and quality of the data (i.e., precision and accuracy).

EQUIPMENT AND SUPPLIES

Adult sampling equipment can be divided into two general categories: Sampling gear and laboratory supplies. Sampling gear is usually specific to the vessel employed for the survey and is discussed below under "Vessel Requirements." Laboratory equipment refers to everything necessary to subsample the catch and preserve the specimens: buckets for subsampling, preserving solution, labels, data sheets, and specimen jars. Also useful are a small scoop, specimen jar rack, dissecting scissors, small spatula, forceps, and a hand digital logger with at least three registers (e.g., blood cell counter). The survey should be planned in enough detail to take the proper amount of supplies. Because space on a vessel is usually at a premium and because running short of supplies is also costly, it is recommended that extra supplies be kept onboard.

SOURCES OF ERRORS, BIASES, AND POTENTIAL PROBLEMS

The most serious source of bias is the selectivity of adult fish sampling gear. As discussed above, suspected biases should be investigated and, if necessary, changes should be made to the gear and/or sampling procedures. A representative sample is achieved when each adult fish has an equal probability of being caught by the sampler; if ripe females are more vulnerable to capture than the rest of the adult population or if fish were more able to avoid the net during certain times of the day, then a representative sample is not achieved, and this fact must be considered. In the survey for *Engraulis mordax*, where these problems were encountered, ripe females were eliminated from the calculation of the spawning fraction and adult sampling was conducted during only a portion of the day.

Error may be introduced when there is geographic heterogeneity in spawning and homogeneous sampling. Close examination of the results and postsurvey stratification, if indicated, is the most direct method of reducing this error. Error may also be introduced when subsampling the catch aboard ship (e.g., an inadvertent preference for large fish); this may be reduced by devising a systematic procedure for selecting fish. Finally, it is important to clean the net between sets; fish can get caught in the webbing and become part of the apparent catch of a subsequent set. Off California, pelagic red crabs sometimes contaminate the catch and abrade the fish; these fish cannot be distinguished from the residual of a previous trawl unless the net is thoroughly flushed between sets.

VESSEL REQUIREMENTS

Because the survey vessel is the most important piece of equipment to be specified, it is prudent to consider the requirements in some detail. The following subsections outline the minimum considerations. Additional specifications and detail in planning will aid in the conduct of the survey. It is impossible to prepare too much.

[3]P. E. Smith, Southw. Fish. Cent., Natl. Mar. Fish. Serv., NOAA, La Jolla, CA 92038, pers. commun. Sept. 1983.

Sea Days Capability

The vessel must be able to take on sufficient provisions and fuel to conduct a major portion of the survey without returning to port. A minimum two-week capability should be required to maintain survey continuity and to obtain samples in a reasonably short period of time. Bear in mind that a port call involves travel time to port, time in port, and travel time back to the next station; delays in sampling can easily become longer than originally anticipated.

Gear Operations

The vessel should be equipped with the specified adult sampling gear rather than bringing new gear aboard. The gear should be clean and in good operating order. The vessel's crew should be proficient in deploying and retrieving the gear as well as repairing minor damage to the net without returning to port. If members of the scientific party will be required to help operate the gear, the number of people and their duties should be clearly specified.

The winch requirements (as outlined above for egg sampling) should be clearly specified and stressed as critical to the conduct of the survey. Other requirements include provisions for measuring the wire angle and washing down the net.

It is most important that any collection operations (egg or adult) which involve the cooperation of the crew and the scientific party be discussed thoroughly and even practiced before the survey begins.

Vessel Speed

Knowledge of the vessel's speed is a key element in the planning of a survey because a major portion of time is spent underway between stations. Speed will vary according to sea conditions and the loading of the vessel; however, a realistic estimate of the expected average speed is very useful. The survey may be planned first and a minimum vessel speed specified as a criterion for vessel selection.

Personnel

The primary requirement for the vessel personnel is that they be adequate in number and sufficiently skilled to accomplish the specified operations. Competence in navigation should be a major requirement; this not only involves human skill but the proper equipment as well. It should be specified that each station must be accurately located and that it is not sufficient to know only the vessel position relative to port or land. As noted above, vessel personnel should know how to operate and repair the adult sampling gear.

Supplies and Specimen Storage

The vessel must have adequate space dedicated to dry storage of sampling supplies and specimens. These requirements must be calculated from the survey plan and can be considerable, particularly for the adult fish specimens. In addition to dry storage, storage space on deck may be specified for sampling gear and freezer storage may be necessary for some specimens.

Laboratory and Work Space

The vessel must have a covered space, well lit and well ventilated, that can be dedicated for use in processing specimens; running water and a drain are essential. Sufficient work space must exist on deck to store and deploy the egg sampler and the adult sampler, to remove their catches, and to subsample in the case of adult catches.

CRUISE PLAN AND WORK SCHEDULES

A cruise plan, distributed to all personnel involved (vessel crews and scientific parties) greatly increases the chance for a successful survey. Such a plan should include a brief statement of the cruise objectives, schedule of port calls, map of the stations and the order in which they are to be occupied, activities to be accomplished at each station, list of the personnel participating and those in charge, and a list of the equipment necessary to accomplish the objectives.

Work schedules should also be made and distributed prior to the cruise. These schedules alert participants as to when they will be working and what they will be doing so that they may be prepared. Careful thought should be given to how many people will be required on each vessel and whether the vessel can accommodate them. As an example, conducting operations 24 hours a day will require two or three work shifts for egg sampling, plus additional people for adult sampling. Each shift should have a designated leader, and one person, either from the crew or from the scientific party, should be in charge of adult sampling operations.

The value of a good plan cannot be emphasized enough. The plan should convey to all participants a clear, concise statement of what is to be accomplished on the cruise and how it is to be done. It should give the impression that a considerable amount of thought and preparation has already been done, and what remains is to carry out the plan. A survey cruise rapidly becomes tedious as the same operations are performed over and over; the plan helps people mark time and keep track of progress.

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