COMPENDIUM ON CYSTIC ECHINOCOCCOSIS

IN AFRICA AND IN MIDDLE EASTERN COUNTRIES WITH SPECIAL REFERENCE TO MOROCCO

EDITORS
F.L. Andersen
H. Ouhelli
M. Kachani

Brigham Young University
Print Services
Provo, UT 84602, USA

COMPENDIUM ON CYSTIC ECHINOCOCCOSIS IN AFRICA AND IN MIDDLE EASTERN COUNTRIES WITH SPECIAL REFERENCE TO MOROCCO

EDITOR

Dr. Ferron L. Andersen

Department of Zoology
Brigham Young University
Provo, Utah 84602, USA

CO-EDITOR

Dr. Hammou Ouhelli

Department of Parasitology
Hassan II Institute of Agronomy
and Veterinary Medicine
Rabat, Morocco

CO-EDITOR

Dr. Malika Kachani

Department of Parasitology
Hassan II Institute of Agronomy
and Veterinary Medicine
Rabat, Morocco

CONTENTS

19. FORMULATING POLICIES FOR CONTROL OF *ECHINOCOCCUS GRANULOSUS*: AN OVERVIEW OF PLANNING, IMPLEMENTATION, AND EVALUATION

Michael A. Gemmell[1] and Peter M. Schantz[2]

[1]World Health Organization
Collaborating Center for Surveillance and Control of Echinococcosis
Department of Clinical Veterinary Medicine
University of Cambridge
Madingley Road
Cambridge CB3 OES, U.K.

[2]Division of Parasitic Diseases
National Center for Infectious Diseases
Centers for Disease Control and Prevention
Public Health Service
Atlanta, Georgia 30333, USA

ABSTRACT: This review identifies some of the steps taken to control *Echinococcus granulosus* in its domestic life cycle. There are at least 4 phases in a control program. In the first, the Planning phase, operational research is undertaken to (1) quantify in baseline surveys the transmission dynamics of the parasite in humans and animals, (2) assess through field trials the most cost-effective frequency of dog-dosing, and (3) estimate costs, benefits, and duration of the Attack phase. Appropriate operational research should be undertaken using the scientific

resources of the region, such as universities and research institutes. When the plan has been completed, it must be approved by the legislature if it is to be funded through that source for its duration.

The Attack phase may have 2 objectives. In a horizontal approach this may consist only of long-term education of the public, upgrading of hygiene at abattoirs, and dog control. This approach may sensitize the population but, on its own, is unlikely to modify transmission. This may continue indefinitely or precede the introduction of a vertical approach with its specific educational program involving community participation to gain support for the treatment of dogs. Because of high costs, an important requirement is to transform this phase as soon as feasible, once transmission to humans becomes an unlikely event, to the Consolidation phase, hence the importance of baseline and continuing surveillance of humans and food animals. This phase suspends testing of dogs or frequent dog treatments, and emphasis is placed on quarantine of premises still submitting infected food animals through an established surveillance program involving meat inspection. Without adequate surveillance and control of animal movement, transformation from the Attack to the Consolidation phase is difficult if not impossible; the program may then be terminated for being no longer cost effective and the parasite may return to its original prevalence. The Consolidation phase is applied permanently in continental programs, but it is possible to reach the Maintenance of Eradication phase in island programs. In both situations, dog registration and border restrictions on entry and re-entry must be retained permanently.

I. INTRODUCTION

As standards of living and education improve and populations drift from rural to urban status, there is clear evidence that cystic echinococcosis (CE), infection by the cestode *Echinococcus granulosus*, declines in humans. Nevertheless, the process of modernization intensifies the need to implement active control programs to accelerate the process. During the past half century several successful as well as unsuccessful programs for controlling this parasite have been undertaken. Experiences gained from them have shown that policies for permanent control must be developed that can be realistically sustained within health budgets that are never large enough to meet all the needs of the community. It follows that business methods more and more must be applied to discriminate between claims for limited discretionary funds available from health and agricultural budgets for planning, implementing, and evaluating control. In addition, it is now known that, because of the long-term nature of a control program, a critical factor for completion is that of obtaining and maintaining sufficient funding from the legislature or governing body. Similarly, loss of confidence by the legislature resulting from inadequate evidence of success may well result in premature withdrawal of funding. Indeed, the collection of effective baseline and subsequent surveillance data must be made so that control policies can be changed and the program remain cost effective if support is to be maintained (Yekutiel, 1980; Gemmell and Lawson, 1986; Gemmell et al., 1986a, 1986b, 1987; Roberts et al., 1986a, 1986b; Gemmell, 1987, 1990, 1993; Schantz, 1993; Ghirotti, 1994; Roberts and Gemmell, 1994; Gemmell and Roberts, 1995, 1996; Schantz et al., 1995).

Two major philosophies have been applied to determine control strategies. The first, a horizontal approach, emphasizes long-term primary health care to enhance socio-economic advancement of the population, thereby improving individual lives and the well-being of the community. This approach includes education, sanitation, upgrading meat inspection, and developing safe water supplies; these measures, however, may not result in control of parasite transmission or achieve a reduction in prevalence of CE. It seems that a control program, if it is to be successful, must be targeted to the parasite, and this must include a vertical approach with the use of, for example, arecoline hydrobromide as a diagnostic agent to test dogs or regular treatment of dogs with praziquantel to eliminate *E. granulosus*. These 2 approaches are not, of course, mutually exclusive, but the vertical approach must include baseline surveys and continuing surveillance of human and animal intermediate hosts to monitor progress (Gemmell et al., 1986a; Gemmell, 1987, 1993; Schantz, 1993).

For the purpose of discussion within this chapter, the following definitions are given:

Control can be described as "the active implementation of a program to limit the prevalence of a specific disease by a recognized authority on instruction from the legislature."

Eradication is "the purposeful reduction of a specific disease prevalence to the point of continued absence of transmission within a specific area by means of a time-limited campaign."

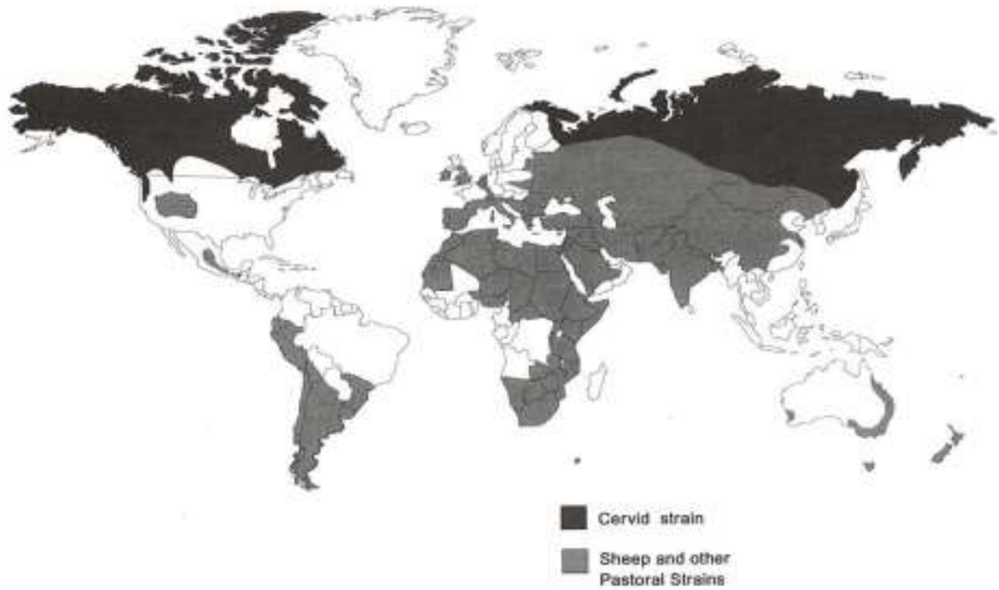


Fig. 19.1. Geographic distribution of *Echinococcus granulosus*.

Preconditions for eradication include (1) absence of adverse ecological factors; (2) adequate administrative, operational, and financial resources; (3) availability of effective tools; (4) favorable epidemiological features; and (5) specific reasons for preferring eradication over control. These specific preconditions preclude considering eradication as a goal for continental programs.

In this chapter an overview is given of administering, planning, implementing, and evaluating echinococcosis control programs from experiences gained from some successful programs initiated during the last half of the 20th century. The measures that can be applied are similar in all endemic regions, but the need for and ability to apply them differ within and among regions (Figs. 19.1 and 19.2).

II. PHASES OF A CONTROL PROGRAM

A program can be divided into 4 phases: namely, Planning, Attack, Consolidation, and Maintenance of Eradication. During the Planning phase the future control authority must be selected and plans made to determine appropriate methods for control, their costs, extent, and duration. During the Attack phase control measures are applied nondiscriminately to the entire host populations at risk. Examples of these measures include mass dog-dosing campaigns and restrictive regulations on dog-feeding practices. During the Consolidation phase at-risk areas or individual farms are identified through surveillance of food animals using trace-back and trace-forward methods, and control measures are targeted to them only. Once the parasite has been potentially eliminated on islands, the Maintenance of Eradication phase can be entered. At this stage all specific measures can be disbanded and vigilance is employed, mainly through normal meat inspection services together with border controls to prevent reintroduction of the parasite. The major objective, where control but not eradication is feasible, is to transform the program permanently from the costly Attack phase to the less costly Consolidation phase as soon as it is technically feasible to do so. In both the Consolidation and Maintenance of Eradication phases, dog registration must continue to be permanently applied (Gemmell et al., 1986a; Gemmell and Lawson, 1986; Gemmell, 1987, 1990, 1993; Gemmell and Roberts, 1995, 1996).

LEVEL OF AWARENESS OF HYDATID DISEASE AS A HEALTH PROBLEM

CATEGORY 1

Countries (states or provinces) with an unquantified health problem, but:

A. Have neither infrastructure nor financial capability to implement surveys.

B. Although financially capable, do not have the infrastructure to implement surveys.

CATEGORY 2

Countries that have more or less quantified their health problem, have the infrastructure and financial capability, but:

A. Have for various reasons considered it unnecessary to apply specific control measures.

B. Have not yet drawn up plans for control.

C. Have not yet received the consent of or have had their plans rejected by the legislature because of inadequate protocols.

CATEGORY 3

Countries that have quantified the health problem, have implemented a control program, but:

A. After a few years, have failed to demonstrate adequate progress.

B. Have reached the stage in control where low prevalence demands a change to more cost-effective measures.

Fig. 19.2 Variations between the levels of public health awareness within endemic regions and political and economic ability to undertake control of *Echinococcus granulosus*.

III. CONSIDERATIONS DURING THE PLANNING PHASE

Operational research in the Planning phase is concerned with quantifying the epidemiological and socio-ecological factors that permit the following estimates to be made: (1) magnitude of parasite transmission, (2) costs of and losses from CE to the community, and (3) benefits from and costs of control. Control of CE may have a limited priority in comparison with other human health problems, or resources needed for control may not be available to cover the whole or even part of the endemic area. Thus, decisions based on investigations in the Planning phase may include (1) taking no action, (2) applying a horizontal approach with emphasis on education, meat inspection and upgrading of slaughterhouses, and so on, or (3) introducing a vertical approach to include positive veterinary intervention with active application of drugs and implementation of specific educational and surveillance programs.

A vertical approach in the Attack phase is costly. Because of delays in the system, reduction in prevalence of echinococcosis in animals takes time after the hyperendemic or endemic status has been transformed to extinction status. Long before this, transmission to humans will have almost ceased. A policy decision must be made during the Planning phase as to whether to (1) remove control altogether, (2) retain control permanently at a much reduced level of activity in a Consolidation phase, or (3) attempt eradication. Thus, as far as it is possible to do so, an important objective in terms of estimating benefits and costs of permanent control in the Planning phase is to estimate the potential time for transfer from the Attack to the Consolidation phase.

It follows that the overall objective of the plan is to develop long-term control policies with potentially low cost-benefit ratios that fall within the resources of the primary health care and veterinary services. If, however, the attack phase is simply terminated at some stage without entering the Consolidation phase, the parasite may revert to its former pre-control level. Thus, removal of all controls when transmission reaches a low level is not a valid option in planning the program. Removal, however, of some of the most costly controls, but retention of others in the Consolidation phase, should not lead to recrudescence when the risk of transmission appears to have become an unlikely event. Permanent control can be achieved most economically by maintaining surveillance of food animals and taking local action, such as quarantine of premises wherever breakdowns are identified through surveillance in food animals.

A. Selection of Options for Control

Based on experiences gained from several control programs described below, 5 options can be discerned. These must be considered when cost-benefit ratios are being compared in the Planning phase.

Option 1 involves a decision not to proceed with control for a variety of reasons, such as lack of resources.

Option 2 involves a horizontal approach, namely, the upgrading of veterinary public health activities, such as improving hygiene at abattoirs, increasing dog control and registration, and applying an educational program effected principally in schools. (It is emphasized here that the provision of tablets for owners to treat their dogs as part of a horizontal approach was applied in 2 countries without effect on the prevalence of echinococcosis in humans or food animals.)

Option 3 is oriented toward preventing dogs from gaining access to raw sheep offal; it uses arecoline hydrobromide as a diagnostic agent in an educational approach to control. With this "slow track" option, the duration of the Attack phase may last for more than 30 yr, although it is possible to transfer to the less costly Consolidation phase earlier, provided legislation can be applied to quarantine sheep flocks still harboring infected animals identified through surveillance systems and supported by appropriate animal health legislation.

Option 4 is a "fast track" approach and includes the application of arecoline in an educational approach as in option 3. In addition, however, to achieve a rapid decline in the Attack phase, the dog population must be drastically reduced and the duration of the Attack phase may be as low as 10–12 yr.

Option 5 is also a "fast track," but in this case all dogs are treated with praziquantel at intervals to be predetermined during the Planning phase. The duration of the Attack phase may be also as short as 10–12 yr.

B. Planning a Horizontal Approach (Option 2)

In several highly endemic situations, particularly where effective structures or funds are not available for control, a vertical approach may not be possible. In this case emphasis may be placed in a Planning phase on developing a horizontal approach by defining losses from CE to human health and the costs of the primary health care methods that might be applied in a long-term educational approach to control, particularly directed at schools. Similarly, baseline surveys of the prevalence of the parasite in animals and methods by which hygiene at abattoirs may be upgraded, and their respective costs, should form part of this approach. As previously implied, these educational and meat hygiene components do not necessarily modify transmission, but they may contribute generally toward improving standards of living and an understanding of the health problem.

C. Planning a Vertical Approach (Options 3, 4, 5)

It is now well documented that climate can play a significant role in determining the duration of infectivity of the egg, and thus the seasonal infection pressure may vary widely within endemic zones (Gemmell, 1993). There is, therefore, a need to ensure that in any survey the data belong to the region in which they have been collected.

Baseline surveys are of fundamental importance in (1) establishing the significance of CE in comparison with other endemic diseases and (2) gaining an insight into the processes of transmission between animals.

The information that should be obtained in the Planning phase includes age-specific prevalence and geographic distribution of human, domestic livestock, and sylvatic animal echinococcosis. It is necessary to identify the main agencies involved in assembling the data on CE from hospital registers, serological laboratories, and health institutes, as well as those veterinary institutes that are available for collection and processing. In most cases this information may have to be acquired by specific surveys and undertaken by planning groups. Surveillance methods are discussed in greater detail in Chapter 4. Experience suggests that this type of operational research is ideally undertaken by coordinating the scientific resources of the region, such as those available at universities and research institutes.

1. Human cystic echinococcosis (CE)

The annual rate of new hospital cases, when properly compiled, is accepted as the most useful data on the significance of CE. When measured continuously over several years, these data can detect regional changes in infection incidence. The baseline information that will contribute most to defining realistic infection levels includes a 5-yr retrospective survey of all proven surgical cases from all hospitals that provide surgery within the region. The data have usually been expressed as the annual rate of new hospital cases (surgical cases only) or total patients per 100,000 of the rural and or/total population. For epidemiological purposes the rate should be broken down by age, sex, ethnic group, residence, occupation, and so on. These data can then be used to estimate economic losses caused by CE in terms of hospital costs, person hours lost, and total and partial handicap for work.

2. Canine echinococcosis

Control programs in the past have used 6-wk intervals for treating dogs with praziquantel. This interval was based on the assumption that dogs became reinfected almost immediately after treatment. Dog-dosing forms the most costly part of the Attack phase. This frequency has now been shown to be not always necessary and sometimes contraindicated, as it may drive *Taenia hydatigena* and *T. ovis* from hyperendemic to endemic status and increase larval populations in the intermediate hosts. Knowledge of the rates of reinfection in dogs with these parasites can be used to estimate (1) the maximum, and thus most economical, interval between treatments to control *E. granulosus*. This must be balanced with (2) as great an interval between treatments as possible so that transmission of the large tapeworms (e.g., *T. ovis*) is not increased, giving rise to an economic problem to agriculture. Subsequent field trials using sentinel sheep can confirm the most cost-effective interval (Gemmell et al., 1986b; Cabrera et al., 1996).

The value and limitations of testing dogs for taeniid tapeworms with arecoline hydrobromide in surveys have been well documented (see FAO/UNEP/WHO, 1981). The most valuable and perhaps only modern use for arecoline testing in the Planning phase is for determining reinfection levels and, thus, the most economic treatment schedules for dogs with praziquantel in the Attack phase (Gemmell et al., 1986b; Cabrera et al., 1996; Gemmell and Roberts, 1996). For these baseline studies to be comparable they should be accompanied by the following information: (1) dose rate applied, (2) thoroughness with which doubtful samples have been excluded from the analysis, (3) methods used to separate worms from feces, and (4) visual aids used to examine the samples. A body of evidence confirms that diagnosis in the laboratory is likely to yield a higher reinfection level than diagnosis in the field, especially where worms less than 5 wk of age, or fewer than 5 worms per sample, are present (Gemmell, 1973).

3. Echinococcosis in food animals

Surveys of prevalence of echinococcosis in livestock, especially sheep, are important for comparing transmission levels within and among regions. Examination of livers and lungs at autopsy remains the only practical method of obtaining these data. Good design and sampling procedures are important, and samples should be large enough to ensure that appropriate comparisons can be made. Information that may be required includes (1) geographic distribution, (2) age-intensity prevalence, (3) lung-liver ratios, and (4) fertility of cysts. Where there is doubt concerning the origin of the animals, data should be excluded from any analyses of the geographic distribution.

Where transmission levels have been quantified, namely in New Zealand, China, and Uruguay, the equilibrium steady state has been defined as endemic with the basic reproduction ratio (R_0) only slightly above unity. For example, New Zealand sheep experienced 0.4 infections/yr with 155–373 eggs. This was similar in an endemic area in China with 0.4 infections/yr with 232 eggs. In Uruguay the number of eggs ingested per infection was 694 with 0.17 infections/per yr, demonstrating more eggs per infection but fewer infections and suggesting a seasonal effect. In all 3 cases the number of eggs was too large and the intervals between infections far too long for the animals to acquire strong permanent immunity to superinfection. This is a key measurement, and the information obtained clearly shows that a dog-dosing program at a relatively low level of intensity would be feasible (Roberts et al., 1986a, 1986b; Ming et al., 1992; Cabrera et al., 1995).

4. Errors in meat inspection

The undifferentiated inclusion of parasites other than *E. granulosus* during meat inspection in echinococcosis surveys invariably leads to gross errors in understanding the local transmission dynamics and resources needed for control. Besides the ubiquitous *T. hydatigena*, other parasites, such as *T. taeniaeformis*, *Toxocara canis*, *Toxascaris leonina*, *Ascaris suum*, *Parascaris equorum*, *Fasciola* spp., and *Fascioloides magna*, are relatively common in the livers of sheep. Lesions that must also be excluded include those caused by *Dictyocaulus filaria* and *Muellerius capillaris*, as well as some bacterial pneumoniases including caseous lymphadenitis (CLA).

5. Sylvatic animal echinococcosis

Effective evaluations of wildlife echinococcosis may require the examination of relatively large numbers of animals in the Planning phase. Methods of capture and sampling populations are described in appropriate journals. An important reason for adequate surveys in the Planning phase is to determine whether transmission to sylvatic hosts is dependent on or independent of domestic animals. In the event that wild animals are involved in spillover situations, these spillover hosts should play no essential part in the Attack phase. This is because they neither need treatment nor serve as indices of progress in control. For this reason surveys on feral and sylvatic intermediate hosts should be made during the Planning phase and toward the end of the Attack phase.

D. Quantifying Costs and Benefits of Control

Mathematical models provide a logical framework within which the dynamics of life cycles can be described. These models provide, via the "threshold theorem" (Kermack and MacKendrick, 1991), a criterion for deciding if a control program can succeed in eliminating the parasite. To use this theorem, one must have an estimate of the basic reproduction ratio (R_0). This can be obtained only if reliable epidemiological data are available in the Planning phase and before the Attack phase is started. These models can be used as the basis for predicting both costs and outcomes of various control options and costs (Roberts et al., 1986a, 1986b; Lawson et al., 1988; Kermack and MacKendrick, 1991; Lawson, 1994; Roberts and Gemmell, 1994; Gemmell and Roberts, 1995, 1996).

For example, the effect of the selected control measure on the prevalence of the parasite in its hosts during the course of the program can be approximated using the equation

$$h = h_{\infty} + (h_0 - h_{\infty})exp(-pt)$$

where h is the parasite infection pressure, and the effect of the measure is to change the steady-state value of h from h_0 to h_{∞}. The exponent p is calculated from

$$p = \frac{h_0 \lambda_{\infty} (1/R_{0(before)} - 1/R_{0(after)})}{h_{\infty} - h_0}$$

where λ_{∞} is the rate of parasite transmission through the system when the control pressure is applied.

Before an analysis can be undertaken, information is required on (1) annual losses due to human disability and death, (2) annual losses due to infection of livestock, and (3) annual costs of the selected control policies. Once annual costs and losses have been determined, discounted costs and losses over the selected time span must be calculated.

Economic analysis can be useful not only for assessing echinococcosis control in comparison with other public health projects, but also for determining the optimum control or eradication strategy to be used against the parasite. Several methods of economic evaluation are available and useful for planning and managing control programs; these include cost-effectiveness analysis (CEA) and cost-benefit analysis (CBA). CEA is useful for determining the least expensive strategy that can achieve a well-defined outcome target or for identifying the optimal strategy to meet an objective given a fixed budget. CBA is more comprehensive than cost-effectiveness analysis; it determines if net benefits of a control program outweigh net costs to society. Methods and applications of economic evaluation to control programs are discussed in greater detail in Chapter 18.

E. Quantifiable Losses from Echinococcosis and Costs of Control

Although it is recognized that control of a human disease imparts much more than just financial benefits, in practice the inclusion of non-monetary aspects into cost-benefit analysis is difficult and largely unsatisfactory. Most studies of losses due to human hydatid disease have, therefore, confined themselves to calculating lost production due to disability and death. They are consequently gross underestimations of the true cost of the disease. Nevertheless, once these limitations are recognized, cost-benefit analysis remains an extremely useful tool for assessing the comparative merits of both different public health projects and different control strategies, especially if used in conjunction with other quantitative and qualitative methods. In New Zealand, for example, 2 control options were studied for *E. granulosus* and 10 for *T. ovis*, giving a total of 20 control options. They were ranked according to their low and high cost-benefit ratios and net damages evaluated over a period of 30 yr. Such information can be most useful for convincing the legislature of the appropriate way to proceed with control and its cost (Lawson et al., 1988; Lawson, 1994).

1. Human cystic echinococcosis (CE)

In patients with CE, quantifiable items include preoperative diagnosis, surgical treatment, hospitalization, post-surgical examinations, medications, and transfers. There are variations among cases so that those complicated by infection, rupture, or difficult access call for much more lengthy hospitalization periods. Quantification becomes more difficult when, in addition to these sequelae, new cases occur in dramatic localizations (such as bones, eyes, brain, and heart). These may result in loss of an organ and/or irreversible sequelae or death.

In this brief analysis the convalescent period should also be considered as an economic loss in view of the well-documented fact that a great proportion of cases occurs in actively working persons and the contribution of their labor to the economy is lost (Beggs, 1985; Bchir et al., 1987, 1989). To this must be added the amount of social security benefit or costs incurred. A realistic contribution to estimates of these losses from this parasitism can be made only if reliable and consistent registers are kept of case histories at all hospitals undertaking surgery.

2. Animal production and economic losses

A determination of the economic impact of echinococcosis in domestic food animals would appear to be a simple task. It would suffice to calculate the number of kilograms of infected viscera condemned in local abattoirs and to multiply them by their value (their price per kg, ton, or some other unit). These calculations showed that in Chile between 1983 and 1989, offal (livers and kidneys alone) were condemned to a value of U.S.$634,563. However, it must be borne in mind that in some endemic areas viscera condemned for human consumption have a residual value because they are used for making pet foods for animals (e.g., dogs, cats, and fish). Preliminary studies carried out also in Region XII in Chile indicated that carcasses of sheep born and slaughtered after implementation of control weighed on average 1 kg more that those born and slaughtered before control (Campano, 1991); thus, echinococcosis may directly impact animal growth.

With respect to economic analyses of control programs, a prospective analysis was performed on a 10-yr project in Sardinia (Attanasio and Palmas, 1984; Attanasio et al., 1985). Assuming achievement of a decline in echinococcosis prevalence in sheep from 80% to 10%, the authors projected the net value gained in improved milk production would be 32.5 billion lires in 1982; thus, the rate of return of such a control program would be equal to 53.6%. Although this projection was based on a number of assumptions, it identifies an operational research area in the Planning phase, the results from which are very useful if support for the program is to be obtained from the legislature.

3. Some costs incurred in applying control

Costs of control will depend on the methods applied but may include the following: (1) training and continuing education of personnel, (2) staff salaries, (3) education of the public, (4) dog control and treatment, including drugs, (5) surveillance of CE in humans, (6) surveillance of intermediate host populations, (7) evaluation of results, (8) vehicle purchases and maintenance, and (9) administration.

Sources of funding for control in part or in full may include (1) fees attached to a dog license or (2) national or provincial government sources, including the budgets of ministries of health, agriculture, and internal affairs.

IV. MONITORING PROGRESS DURING THE ATTACK PHASE

A. Surveillance of Human Cystic Echinococcosis (CE)

Immunodiagnostic tests are used not only for pre- and post-treatment screening, but also for surveys. The more common primary screening tests use crude hydatid antigens and include latex agglutination (LA), indirect hemagglutination (IHA), and enzyme-linked immunosorbent assay (ELISA). Recent literature is vast and principally concerned with specificity and sensitivity, hybridoma technology, immuno-affinity chromatography, and immunoblotting. These now provide improved reagents for more sensitive and specific tests based on measurements of circulating antibodies and antigens (Craig, 1993; Schantz, 1993; Schantz et al., 1995).

Modern techniques for pre- and post-surgical scanning of CE also now include computerized axial tomography (CT) and angiography. CT determines with precision the volume and density of the fluid and/or anatomical location of cysts and is the method of choice in the hospital situation, particularly for post-surgical evaluation of residual pericyst cavities and after drug treatment. In the field, due to its portability, ultrasound scanning provides an excellent tool for longitudinal assays of cyst growth and death (Beggs, 1983, 1985; Mlika et al., 1984, 1986; Macpherson et al., 1987; Perdomo, 1990; Pawlowski, 1993; Ammann and Eckert, 1995).

While these tests may be useful in the Planning phase, the criterion for evaluating the efficacy of control should be changes in surgical incidence rates of CE rather than changes in serological and echographic prevalence levels that include cysts that are removed surgically as well as those that will always remain asymptomatic or even disappear (Tsenletis et al., 1983; Karpathios et al., 1985; Bchir et al., 1987, 1989). Nevertheless, to measure progress, costs must be added to the surveillance program if any of them are applied in the Attack phase. There will be costs, of course, such as medical diagnosis and treatment, and, thus, losses from CE.

B. Surveillance in Food Animals

In several cases surveillance of echinococcosis in food animals has been very limited or even omitted. This has seriously reduced the value of a control program. Furthermore, lack of information prevents transformation from the Attack to the Consolidation phase. Methods of surveillance to be applied in the Attack phase must be defined in the Planning phase when baseline data are being collected. Usually, cysts in the liver have been used as the criterion of infection. Ideally, lungs should also be included, taking care to relate both organs to the same infected animal in each age-cohort during routine meat inspection. A more sensitive method when measuring changes in infection levels involves pasturing sentinel young sheep as an indicator of progress (Lloyd et al., 1991). In addition, special surveys are needed during the Planning phase, including measuring age-intensity prevalence (Cabrera et al., 1995). In these cases, livers and lungs are cut into 2-mm slices and examined histologically. Large, thick slices are cut in half and small lesions embedded whole. Sections can be stained with hematoxylin and eosin and *E. granulosus* positively identified. PAS stain is also valuable for demonstrating the laminated membrane and, thus, can differentiate *E. granulosus* from other liver cysts.

C. Surveillance in Definitive Hosts

The most accurate indicator of the prevalence and variation in the infective pattern of adult *E. granulosus* in dogs involves necropsy of the small intestine. However, it is rarely possible to obtain sufficient animals in each class (working, hunting, stray, or pet) to evaluate completely the epidemiological factors involved in a causal relationship with CE in humans. The method has the most application as a survey tool where feral and unwanted dogs occur.

Now that praziquantel is used routinely to treat dogs in control programs, arecoline has less of a role to play in education or surveillance during the Attack phase. An alternative approach to diagnosis is based on fecal antigen detecting antibody sandwich technique.

This has shown promise because antigen can be detected shortly after infection and the level declines rapidly following expulsion of the worms. The sensitivity and specificity have been estimated at 87.5% and 96%, respectively (Allan et al., 1992; Deplazes et al., 1992; Craig, 1993; Craig et al., 1994). Further work may show that the coproantigen test may find a useful role in identifying dogs that become reinfected in the Consolidation and Attack phases when qualitative rather then quantitative infection data may be required.

V. EVALUATION OF ATTACK PHASE IN ISLAND AND CONTINENTAL CONTROL PROGRAMS

The island and continental control programs described in this section have differed from each other in administration, resources used, methods applied, and/or rate of decline in transmission. Changes that have occurred in the prevalence of *E. granulosus* in adult sheep have been used to compare progress and identify problems during the Attack phase.

A. Comparison of Effectiveness of Control Options

1. Option 2—Horizontal approach

Option 2, involving education, was used for 20 yr, beginning in 1937, in New Zealand. Although posters and pamphlets were directed at the rural population and schools, and facilities and hygiene were generally upgraded at abattoirs, no impact was observed on the prevalence of *E. granulosus* in humans or food animals (data not shown). A similar finding was reported from Uruguay between 1970 and 1990 (Fig.19.3). In other words, although an awareness of the problem was created, no evidence for a decline in prevalence could be discerned in both island and continental programs. The role that might be played by television in education has not yet been evaluated.

2. Option 3—Educational approach with arecoline surveillance

Following an intensive community participation educational program (Begg, 1961; Beard, 1987, 1988), New Zealand and Tasmania adopted a "slow track" with an

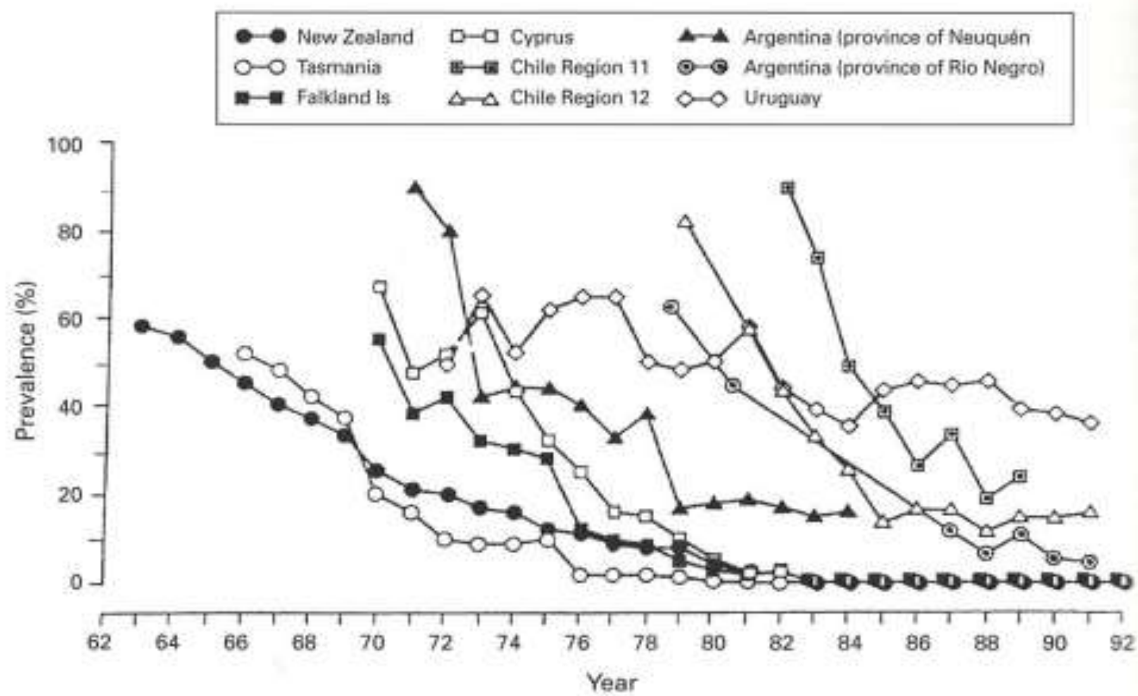


Fig. 19.3. Prevalence of *Echinococcus granulosus* in adult sheep during control in Uruguay (Option 2); New Zealand and Tasmania (Option 3); Cyprus (Option 4); and the Falkland Islands, Argentina, and Chile (Option 5).

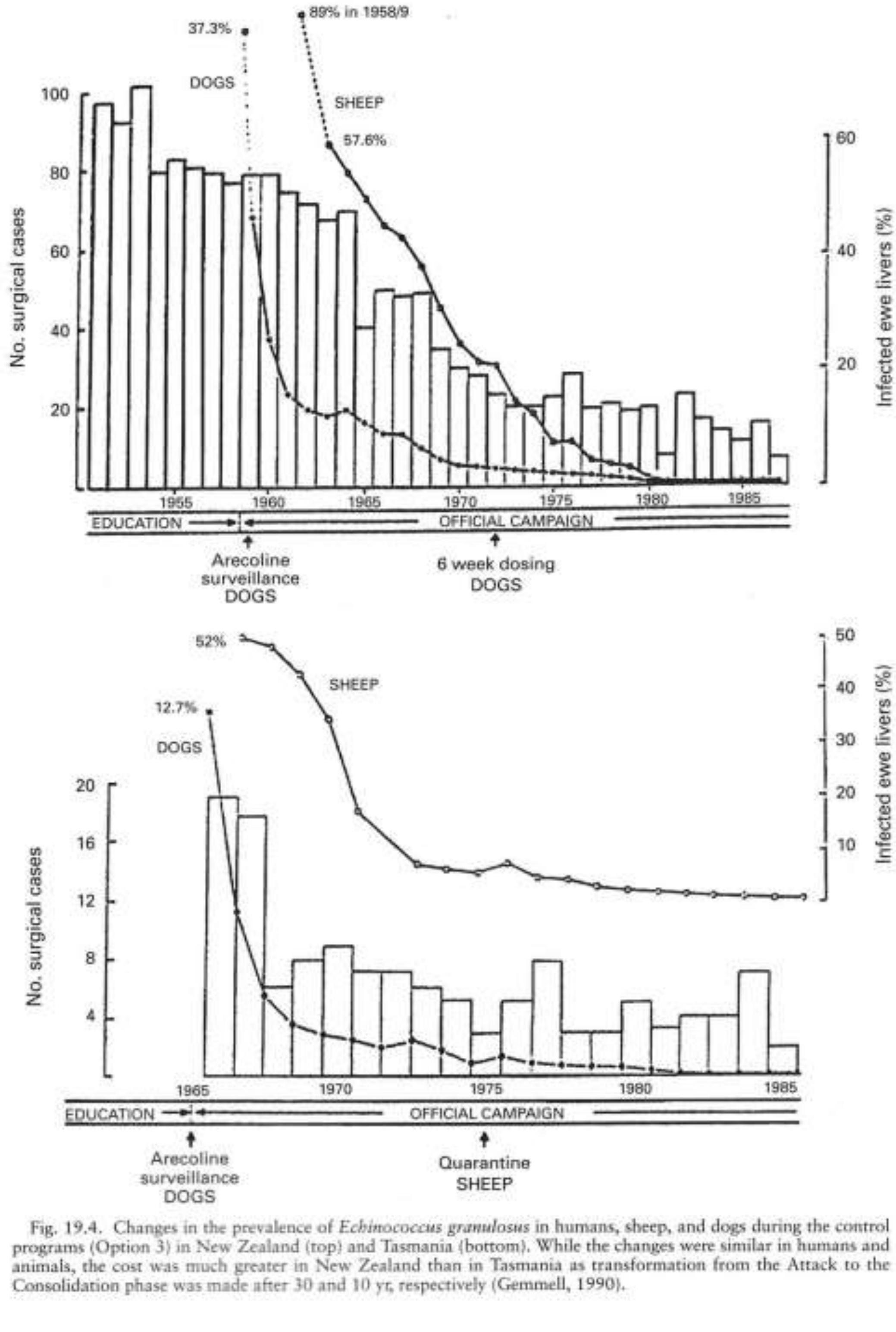


Fig. 19.4. Changes in the prevalence of *Echinococcus granulosus* in humans, sheep, and dogs during the control programs (Option 3) in New Zealand (top) and Tasmania (bottom). While the changes were similar in humans and animals, the cost was much greater in New Zealand than in Tasmania as transformation from the Attack to the Consolidation phase was made after 30 and 10 yr, respectively (Gemmell, 1990).

arecoline dog-testing program. In the former the program commenced in 1959 with an attempt to test all dogs with arecoline hydrobromide up to 4 times each year, but this was changed in 1972 to a 6-wk, nondiscriminatory dog-dosing program to control *T. ovis* (Option 5). This program was administered by a National Hydatids Council (under the New Zealand Hydatids Act, 1959) and funded primarily by a dog tax added to the dog registration fee. Following transfer to the Ministry of Agriculture in 1990, the 30-yr Attack phase was transformed into the Consolidation phase with surveillance of the sheep population and quarantine of infected farms. By that time the parasite was rarely detected during routine meat inspection of food animals (Anonymous, 1961; Gemmell, 1990; Heath and Kasper, 1991).)

In Tasmania the Attack phase using a dog-testing program was introduced in 1965 and administered and funded by the Department of Agriculture. Within 10–12 yr this Attack phase was transformed to the Consolidation phase with a targeted approach using surveillance of sheep with subsequent quarantine of farms and finally purchase and slaughter of infected animals in 1994 (Anonymous, 1964; McConnell and Green, 1979; McConnell, 1987; Gemmell, 1990).

While improvements to human health and prevalence in sheep were similar in both programs, the cost of the Attack phase was much less in Tasmania than in New Zealand. This was because it was possible in the former through the Department of Agriculture to transfer to the Consolidation phase within 10 yr, but only after 30 yr with the latter when the Ministry of Agriculture assumed responsibility for the program (Figs. 19.3 and 19.4).

3. Option—4 Educational approach with positive dog euthanasia policy

Cyprus adopted an approach in 1970 similar to that used in New Zealand and Tasmania with dog testing 3 times yearly. However, from 1971 a "fast-track" was achieved by drastically reducing the dog population in the Attack phase by about 85,000 animals. This program was undertaken and funded by the Ministry of Agriculture. Echinococcosis was considered to have been eradicated by this attack in 1985 (Polydorou, 1971, 1974, 1976, 1977, 1980, 1981, 1984). However, this was not the case, and during the mid-1990s in the Greek-administered part of the Republic of Cyprus, the program was transferred back from the Maintenance of Eradication stage by the Ministry of Agriculture to the Consolidation phase with surveillance of food animals and quarantine of farms with infected livestock.

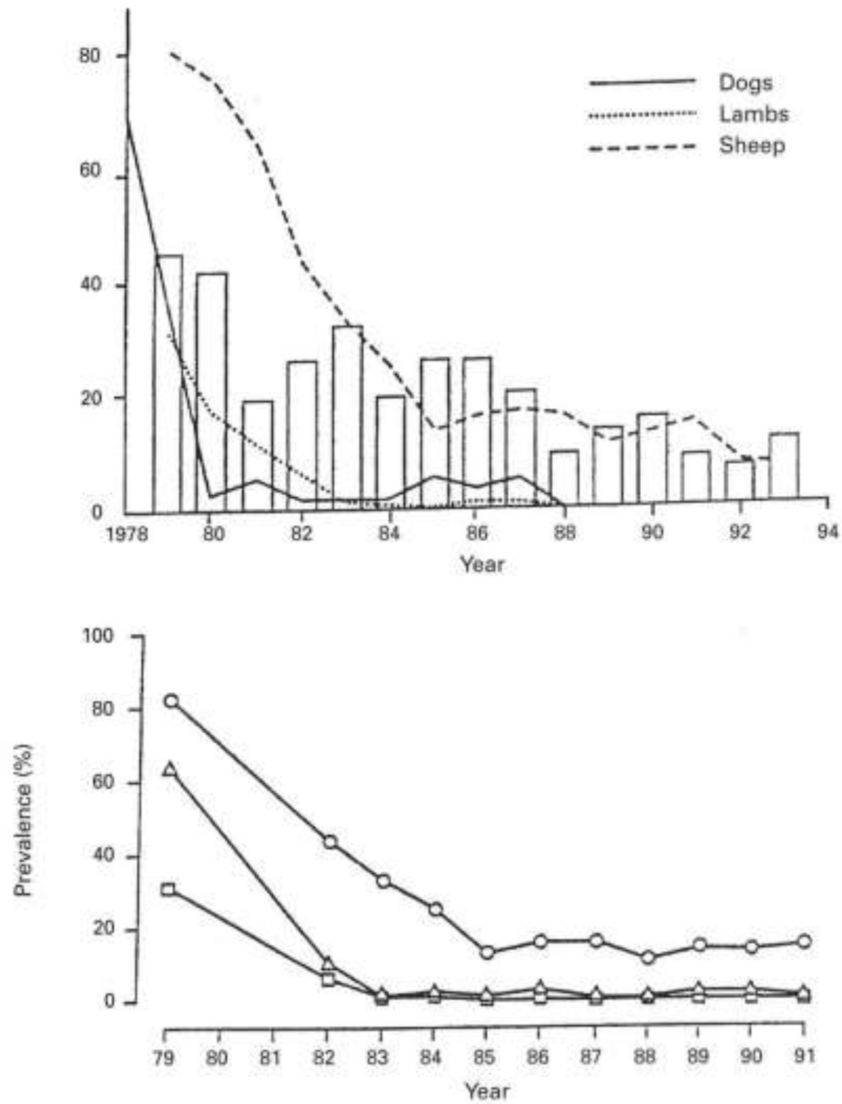
4. Option—5 Frequent dog-dosing campaigns

The Falkland (Malvinas) Islands, Argentina (Neuquén and Rio Negro Provinces) and Chile (Regions II and XII) achieved a fast track initially by applying a 6-wk dog-dosing program. This substantially reduced the prevalence of *E. granulosus* in food animals without the need to reduce the dog population (Fig 19.3). Both Chilean programs and the Falkland Islands used the Ministry of Agriculture and carried out a formal surveillance of the sheep population. In contrast, this was difficult to achieve in regional programs funded by Ministries of Health (Anonymous, 1989; Larrieu et al., 1989; Ogueta, 1989; Ogueta et al., 1989; Campaño, 1991).

5. Dog-control policies

All 3 successful island programs, namely New Zealand, Cyprus, and Tasmania, emphasized education through arecoline surveillance. Possible numbers of registered and unregistered dogs were 500,000, 100,000, and 50,000 before control, respectively. In all 3, dog registration was mandatory. Only in Cyprus, due to the high number of owned dogs and ownerless strays, was an aggressive euthanasia policy adopted. The results showed that within 10–12 yr of adopting this policy transmission of *E. granulosus* to sheep almost ceased in Cyprus, whereas the duration of transmission was at least twice as long in New Zealand and Tasmania (Fig. 19.3). However, irrespective of different dog control policies, transmission of new cases of CE almost ceased in all 3 programs within 10–12 yr.

Comparing the decline in prevalence of echinococcosis in sheep in Cyprus, achieved largely through its positive dog euthanasia policy, with campaigns that applied a 6-wk dog-dosing program without such a policy, namely Neuquén and Rio Negro Provinces in Argentina and Regions XI and XII in Chile, the initial slopes for the decline in prevalence of echinococcosis in sheep were rapid and



Number of dog treatments													
by veterinarians	2	8	8	8	6	4	4	4	2	1	2	2	4
owners						4	4	0	2	1	0	0	4

Fig. 19.5. Changes in the prevalence of *Echinococcus granulosus* in Region XII, Chile (Option 5; Anonymous, 1989a, 1989b; Ogueta, 1989; Ogueta et al., 1989; Campano, 1992).

Top: Changes in the number of human cases (bars) and prevalence in adult sheep, lambs, and dogs.

Bottom: Illustration of the need to perform baseline surveys and, subsequently, continuing surveillance to identify progress and problems arising during control. The plateau in the prevalence in adult sheep (○), 2-tooth sheep (△), and lambs (□) appears to be related to a premature reduction in dog-treatment intervals with praziquantel during the Attack phase. With these data, it was possible to retain support for the program when a plateau occurred in the prevalence in the sheep population. If the baseline data had not been collected until after the program had started (say 1983), progress could not have been shown (say in 1987), and funding could have justifiably been withdrawn before the Attack phase had been completed. This also illustrates the need to retain a full dog-dosing commitment until the transformation to the Consolidation phase has been made.

similar; but only in the dog-dosing programs was a plateau in prevalence reached near the end of the Attack phase (Figs. 19.3 and 19.5). This seems to have resulted from an increase in the duration between dog-dosing treatments in the Attack phase without entry into the Consolidation phase.

VI. TRANSFORMATION TO THE CONSOLIDATION PHASE

There are considerable financial advantages in transforming to the Consolidation phase as soon as possible (Fig. 19.4). Three programs have made this transformation, namely, New Zealand, Tasmania, and the Greek area of Cyprus. Very little is yet known of the intensity of reinfection that may occur once transformation is adopted or of the methods that must be adopted to avoid it. From preliminary studies in these programs it seems clear that an essential method includes the surveillance of food animals through meat inspection by trace-forward and trace-back methods. This must be supported by animal movement legislation permitting quarantine of the premises where infected food animals have been maintained. Neither arecoline nor coproantigen diagnostic procedures may be sensitive enough to identify the particular dog(s) if low worm burdens are involved. Thus, control may have to be supported by a short-term reintroduction of treatment of dogs prescribed within a wide boundary of the infected premises. Permanent border controls must be maintained for food animals and dogs, as well as registration of the latter.

VII. ADMINISTRATION, LEGISLATION, AND FUNDING

There are 2 models of program administration. The first creates through specific legislation a national or regional executive body with responsibility for administering

ADMINISTRATION OF ECHINOCOCCOSIS CONTROL PROGRAMS

	MINISTRY OF AGRICULTURE
Advantages:	Funded by the legislature.
	Relatively easy to develop surveillance of food animals; easy transformation from "Attack" to "Consolidation" phase.
Disadvantages:	Difficulty in collecting dog tax and confirming dog registration; limited educational contribution.
	MINISTRY OF HEALTH
Advantages:	Funded by the legislature.
	Emphasis on education for improving human health.
Disadvantages:	Difficulty in collecting dog tax and confirming dog registration, applying surveillance of food animals, and transforming from "Attack" to "Consolidation" phase.
	COUNCIL OR COMMISSION
Advantages:	Local management (department or country council) with access to dog registration and local taxes to fund "Attack" phase with dog-dosing or testing.
Disadvantages:	Unable to transform from "Attack" to "Consolidation" phase with no access to surveillance of food animals.

Fig. 19.6 Summary of advantages and disadvantages of administrations used for the control of echinococcosis.

the control program. The second utilizes an existing government organization (such as a human or an animal health ministry), which is directed by the legislature to plan and, if economically acceptable to it, proceed with surveillance and control. To an extent, the former is likely to be funded through a dog tax and the latter through the legislature.

Depending on the program to be adopted, areas requiring legislation may include (1) meat inspection and effective disposal of offal at abattoirs and prevention of clandestine removal of viscera; (2) banning dogs from abattoirs and butcher shops with closure, if necessary; (3) prevention of feeding of raw offal to dogs including inspection of offal-disposal facilities on farms or other premises where food animals are killed; (4) control of dogs including registration, compulsory submission of dogs for dosing, and elimination of unwanted dogs; as well as (5) quarantine of premises with infected livestock through animal health and movement control legislation.

All programs reviewed confirm that the Attack phase is labor intensive and costly. Where options 3, 4, or 5 have been applied and dog-dosing or testing has been undertaken by trained personnel, a relatively rapid reduction in CE in all age groups of food animals was achieved. It seems that once this phase has been introduced, it should not be relaxed until the Consolidation phase can be introduced with quarantine and movement control of food animals. The evidence suggests that the veterinary component of a human health control authority tends toward maintaining dog-dosing and testing activities in the Attack phase indefinitely. In contrast, those of an agricultural authority tend to transfer these activities to surveillance and animal movement control as soon as it is technically feasible. This transformation can be made only if the control authority is able to provide an effective baseline and continuing surveillance program (Fig. 19.5). Both phases can be entered with programs administered by animal health agencies, but only with difficulty by those with public health administrations or not at all by programs administered by councils or commissions (Fig. 19.6).

Advantages of using a ministry of health as the controlling authority include (1) the value of its health educational programs and (2) justification to apply to the legislature for funds from the health budget to limit a serious health problem. However, the advantages of using a ministry of agriculture outweigh the former. They include not only applying animal health legislation to transform the program from the Attack to the Consolidation phase but also (1) veterinary experience with control of other animal diseases, (2) use of established laboratory and field services, (3) uniformity in veterinary staff training, and (4) establishment of effective trace-forward and trace-back systems.

LITERATURE CITED

Allan, J.C., et al. 1992. Coproantigen detection for immunodiagnosis of echinococcosis and taeniasis in dogs and humans. Parasitology **104**:347–355.

Anonymous. 1961. Annual reports of the National Hydatids Council. Ministry of Agriculture and Fisheries, Wellington, New Zealand, 1961–1989.

_______. 1964. Annual reports and statement of accounts. Tasmanian Hydatids Eradication Council, Hobart, Tasmania, 1964–1988.

_______. 1989. Evaluación del proyecto de control de la hidatidosis en la XII Region de Chile, Periodo 83/87. Servicio de Agricola y Ganadero, Ministerio de Agricultura, Santiago, Chile, p.72.

Ammann, R.W., and J. Eckert. 1995. Clinical diagnosis and treatment of echinococcosis in humans. *In* *Echinococcus* and hydatid disease, R.C.A. Thompson and A.J. Lymbery (eds.). CAB International, Wallingford, U.K., p. 411–463.

Attanasio, E., and C. Palmas. 1984. Cost-effective analysis of echinococcosis/hydatidosis eradication project in Sardinia. Social Science and Medicine **19**:1067–1072.

_______, G. Ferretti, and C. Palmas. 1985. Hydatidosis in Sardinia: review and recommendations. Transactions of the Royal Society of Tropical Medicine and Hygiene **79**:154–158.

Bchir, A., B. Larouze, H. Bouhaouia, L. Bouden, and M. Jemmali. 1987. Echotomographic evidence for a highly endemic focus of hydatidosis in central Tunisia. Lancet **2**:684.

_______, et al. 1989. Distribution of surgical hydatidosis in central Tunisia (1982–1985). Acta Tropica **46**:47–53.

Beard, T.C. 1987. Human hydatid disease in Tasmania. *In* Epidemiology in Tasmania, H. King (ed.). Brolga Press, Canberra, Australia, p. 77–88.

_______. 1988. Human behavior and the ethics of coercion. Medical Journal of Australia **148**:82–85.

Begg, N.C. 1961. The campaign against hydatid disease: an experience in health education. New Zealand Medical Journal **60**:229–234.

Beggs, J. 1983. The radiological appearance of hydatid disease of the liver. Clinical Radiology **34**:555–563.

_______. 1985. The radiology of hydatid disease. American Journal of Roentgenology and Radium Therapy and Nuclear Medicine **145**:639–648.

Cabrera, P.A., et al. 1995. Transmission dynamics of *Echinococcus granulosus*, *Taenia hydatigena* and *Taenia ovis* in sheep. International Journal for Parasitology 25:807–813.

_______, et al. 1996. Rates of reinfection with *Echinococcus granulosus*, *Taenia hydatigena* and other cestodes in rural dogs in Uruguay. International Journal for Parasitology 26:79–83.

Campaño, S. 1991. La hidatidosis equinococcosis en Chile: su historia, status y control. Informe de la Asociación Internacional de Hidatidología, Filial Chile, Santiago, Chile, p. 69.

Craig, P.S. 1993. Immunodiagnosis of *Echinococcus granulosus*. *In* Compendium on cystic echinococcosis—with special reference to the Xinjiang Uygur Autonomous Region, The People's Republic of China, F.L. Andersen, J. Chai, and F. Liu (eds.). Brigham Young University Print Services, Provo, Utah, USA, p. 85–118.

_______, et al. 1994. Diagnosis of canine echinococcosis: comparison of coproantigen and serum antibody test with arecoline purgation in Uruguay. Veterinary Parasitology 56:293–301.

Deplazes, P., et al. 1992. Detection of echinococcosis coproantigen by enzyme-linked immunosorbent assay in dogs, dingoes and foxes. Parasitology Research 78:303–308.

FAO/UNEP/WHO. 1981. Guidelines for surveillance, prevention and control of echinococcosis/hydatidosis, J. Eckert, M.A. Gemmell, and E.J.L. Soulsby (eds.). World Health Organization, Geneva, Switzerland, VPH/ 81.28. 147 p.

Gemmell, M.A. 1973. Surveillance of *Echinococcus granulosus* in dogs with arecoline hydrobromide. Bulletin of the World Health Organization 48:649–652.

_______. 1987. A critical approach to the concepts of control and eradication of echinococcosis/hydatidosis and taeniasis/cysticercosis. International Journal for Parasitology 17:465–472.

_______. 1990. Australasian contributions to an understanding of the epidemiology and control of hydatid disease caused by *Echinococcus granulosus*: past, present and future. International Journal for Parasitology 20: 431–458.

_______. 1993 Quantifying the transmission dynamics of the family Taeniidae with particular reference to *Echinococcus* spp. *In* Compendium on cystic echinococcosis—with special reference to the Xinjiang Uygur Autonomous Region, The People's Republic of China, F.L. Andersen, J. Chai, and F. Liu (eds.). Brigham Young University Print Services, Provo, Utah, USA, p. 57–73.

_______, and J.R. Lawson. 1986. Epidemiology and control of hydatid disease. *In* Biology of echinococcosis and hydatid disease, R.C.A. Thompson (ed.). George Allen & Unwin, London, p. 189–216.

_______, and M.G. Roberts. 1995. Modelling echinococcosis life-cycles. *In Echinococcus* and hydatid disease, R.C.A. Thompson and A.J. Lymbery (eds.). CAB International, Wallingford, U.K., p. 334–354.

_______, and _______. 1996. Echinococcosis. *In* Textbook on zoonosis control, S.R. Palmer, E.J.L. Soulsby, and D.I.H. Simpson (eds.). Oxford University Press, Oxford, U.K. In press.

_______, J.R. Lawson, and M.G. Roberts. 1986a. Control of echinococcosis/hydatidosis. Bulletin of the World Health Organization 64:333–339.

_______, _______, and _______. 1987. Towards global control of cystic and alveolar hydatid diseases. Parasitology Today 3:144–151.

_______, _______, _______, B.R. Kerin, and C.J. Mason. 1986b. Population dynamics in echinococcosis and cysticercosis: evaluation of the biological parameters of *Taenia hydatigena* and *T. ovis* and comparison with those of *Echinococcus granulosus*. Parasitology 94:161–180.

Ghirotti, M. 1994. Planning echinococcosis/hydatidosis control: a methodological approach. ISS/WHO/FAO-CC/IZST/94.24, p. 64.

Heath, D.D., and Kasper, K.C. 1991. The final stages of eradication of *Echinococcus granulosus* from New Zealand. Archivos de la Hidatidosis 30:123–128.

Karpathios, T., et al. 1985. Statistical aspects of hydatid disease in Greek adults. American Journal of Tropical Medicine and Hygiene 34:124–128.

Kermack, W.O., and A.G. MacKendrick. 1991. Contributions to the mathematical theory of epidemics. Bulletin of Mathematical Biology 53:33–55.

Larrieu, E., R. de la Fuente, A. Aquino, M.T. Costa, and F. Vargas. 1989. Control of hydatidosis in the Rio Negro province of Argentina. Veterinary Medical Review 60:54–59.

Lawson, J.R. 1994. Hydatid disease and sheep measles. The history of their control and the economics of a recent change of control policy. New Zealand Journal of Zoology 21:83–89.

_______, M.G. Roberts, M.A. Gemmell, and S.J. Best. 1988. Population dynamics in echinococcosis and cysticercosis: economic assessment of control strategies for *Echinococcus granulosus*, *Taenia ovis* and *T. hydatigena*. Parasitology 97:1–15.

Lloyd, S., S.C. Martin, T.M.H. Walters, and E.J.L. Soulsby. 1991. Use of sentinel lambs for early monitoring of the South Powys hydatidosis control scheme: prevalence of echinococcosis and some other helminths. Veterinary Record (July) 27:73–76.

Macpherson, C., T. Romig, E. Zeyhle, P. Rees, and J. Were. 1987. Portable ultrasound scanner versus serology in screening for hydatid cysts in a nomadic population. Lancet 2:259–261.

McConnell, J.D. 1987. Hydatid disease in Tasmania: control in animals, H. King (ed.). Brolga Press Canberra, Australia, p. 61–75.

_______, and R.J. Green. 1979. The control of hydatid disease in Tasmania. Australian Veterinary Journal 55:140–145.

Ming, R., H.D. Tolley, F.L. Andersen, J. Chai, and Y. Sultan. 1992. Frequency distribution of *Echinococcus granulosus* hydatid cysts in sheep populations in the Xinjiang Uygur Autonomous Region, China. Veterinary Parasitology 44:223–241.

Mlika, N., et al. 1984. Serological survey of human hydatid disease in high-risk populations from central Tunisia. American Journal of Tropical Medicine and Hygiene 13:1182–1184.

_______, et al. 1986. Echotomographic and serological screening for hydatidosis—Tunisian village. American Journal of Tropical Medicine and Hygiene 35: 815–817.

Ogueta, M.V. 1989. Control de la hidatidosis en Chile. Archivos Internacionales de Hidatidosis **29**:180–192.

_______, S. Chacon, and C. Bonilla. 1989. Diagnóstico de situación de hidatidosis ovina y echinococcosis canina XI Región, Chile. Archivos Internacionales de Hidatidosis **29**:193–202.

Pawlowski, Z.S. 1993. Critical points in the clinical management of cystic echinococcosis. *In* Compendium on cystic echinococcosis—with special reference to the Xinjiang Uygur Autonomous Region, The People's Republic of China, F.L. Andersen, J. Chai, and F. Liu (eds.). Brigham Young University Print Services, Provo, Utah, USA, p. 119–131.

Perdomo, R., et al. 1990. Estudio epidemiológico de hidatidosis. Detección precoz por ultrasonido en areas de alto riesgo. Revista de Medicina del Uruguay **4**:34–47.

Polydorou, K. 1971. Hydatid disease in Cyprus. Bulletin de l'Office international des Epizooties **76**:611–619.

_______. 1974. The sanitary position and methods of control in Cyprus. Bulletin de l'Office International des Epizooties **82**:379–384.

_______. 1976. The control of the dog population as the first objective of the anti-echinococcosis campaign in Cyprus. Bulletin de l'Office International des Epizooties **86**:705-715.

_______. 1977. Anti-echinococcosis campaign in Cyprus. Tropical Animal Health and Production **9**:141–146.

_______. 1980. The control of echinococcosis in Cyprus. FAO World Animal Reviews **33**:19–25.

_______. 1981. The national echinococcosis campaign in Cyprus. Infection in dogs: according to use, age, sex and breed. Bulletin de l'Office International des Epizooties **93**:1303–1307.

_______. 1984. How echinococcosis was conquered in Cyprus. World Health Forum **5**:160-164.

Roberts, M.G., and M.A. Gemmell. 1994. Echinococcosis. *In* Parasitic and infectious diseases, M.E. Scott and G. Smith (eds.). Academic Press Inc., London, p. 249–262.

_______, Lawson, J.R. and Gemmell, M.A. 1986a. Population dynamics in echinococcosis and cysticercosis: mathematical model of the life cycle of *Echinococcus granulosus*. Parasitology **92**:621–641.

_______, _______, and _______. 1986b. Epidemiology and control of hydatidosis and cysticercosis. *In* Proceedings of the Pacific Statistical Congress, I.S. Manley and F.C. Lamb (eds.). Auckland, New Zealand, 20–24 May 1985.

Schantz, P.M. 1993. Surveillance and surveys for cystic echinococcosis. *In* Compendium on cystic echinococcosis—with special reference to the Xinjiang Uygur Autonomous Region, The People's Republic of China, F.L. Andersen, J. Chai, and F. Liu (eds.). Brigham Young University Print Services, Provo, Utah, USA, p. 74–84.

_______, et al. 1995. Epidemiology and control of hydatid disease. *In Echinococcus* and hydatid disease, R.C.A. Thompson and A.J. Lymbery (eds.). CAB International, Wallingford, U.K., p. 233–331.

Tselentis, J., et al. 1983. Hydatid disease in asymptomatic young carriers in northern Greece. American Journal of Tropical Medicine and Hygiene **32**:1452–1463.

Yekutiel, P. 1980. Eradication of infectious diseases: a critical study. *In* Contributions to epidemiology and statistics, Vol. 2, M.A. Klingsberg (ed.). Karger, Basel, New York, p. 204.