The Sea-level Canal Controversy

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ABSTRACT

The biological consequences of the proposed sea-level canal in Central America have been the subject of considerable recent discussion. Much of the commentary has been presented by non-biologists with an imperfect understanding of the subject. Some biologists have also presented one-sided views. It is important that the alternative biological results of a new canal be considered in their proper perspective, and where necessary additional data should be obtained in order to make rational judgement on these potentially far-reaching ecological situations.

In a recent article (I. Rubinoff, 1968), I suggested that the proposed construction of a sea-level canal in Central America posed a potential threat to the ecology of the oceans in this area and at the same time provided a remarkable research opportunity. My position is that we are not certain what the consequences of faunal mixing will be; therefore I recommended appropriate studies to permit both proper evaluation of potential biological danger and exploitation of a unique scientific opportunity.

These suggestions provoked numerous comments, including critical ones (Sheffey, 1968; Weathersbee, 1968; Cusack, 1969; Hillaby, 1969; Mueller, 1969; Topp, 1969; Hubbs, MS.). Some of these criticisms were valid and/or matters of opinion about which there can be reasonable argument. Others, unfortunately, would appear to have been based upon false data or very dubious hypotheses.

The errors fall into three categories: (1) factual misinformation on what has passed, or is passing, through the present (lock and freshwater) canal; (2) conceptual misunderstandings of what may happen if and when the sea-level canal is completed and the biotas are allowed to mix; and (3) unjustified scepticism about the usefulness of a biological survey before construction of a sea-level canal.

Engineers with limited biological knowledge, who have assured us that nothing will happen, are as culpable as biologists who over-extrapolate their limited data into prophecies of doom. The fact that the sea-level canal may have far-reaching effects is no excuse for the relaxation of scientific judgement and reasoned analysis (I. Rubinoff, 1969). What I would like to consider here is the evaluation of some of these recent discussions.

TRANSPORT THROUGH THE PRESENT CANAL

Euryhaline organisms (those which can tolerate a wide range of salinity) can migrate actively by swimming or they may be passively transported by 'hitch-hiking' on ships. This passive transport can occur in two forms: by attachment ('fouling') on ships' bottoms, or in ballast tanks—i.e. when the water loaded in one area of ocean is later discharged in another. This latter form of transport is also available to stenohaline organisms (those with narrow salinity tolerances). There have been some qualitative studies of these subjects (Chesher, 1968; Menzies, 1968; R. W. & I. Rubinoff, 1969), but no quantitative measurements have been made.

There are surprisingly few data on successful new colonizations of bodies of water in this region. A number of marine species (Tarpon, Snook, Jacks, etc.) are known to have invaded the fresh waters of Gatun

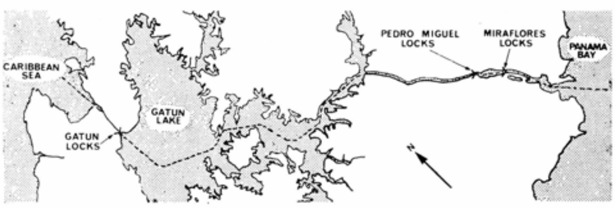

Fig. 1. *Sketch-map of Panama Canal. The isthmus is* 50 *miles* (80 *ml*) *wide in the canal zone.*

Lake, Panama Canal (Fig. 1). Presumably they occasionally pass through the locks in both directions. With the single exception of a small goby (R. W. & I. Rubinoff, 1968), however, there is no species which is known to have moved from one ocean to the other,

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and established a successful breeding colony in the new habitat; moreover, this one exception occurred in very peculiar ecological circumstances.

Many authors have failed to appreciate the fact that the occasional introduction of a few individuals into a new environment does not necessarily constitute a successful colonization. There is a minimum number (which varies with the species and situation) of individuals that is necessary to effect a colonization (i.e. breeding* and population increase). This number is called the 'propagule'† (MacArthur & Wilson, 1967; Simberloff & Wilson, 1969).

The problem of achieving propagule-sized populations is also inherent in the two forms of passive transport. While the potential for transport of marine organisms as ship-fouling or in ballast tanks would seem to be enormous, there are factors which add considerably to the rigours of such a trip.

Transport as Fouling

In order to pass successfully through the present Panama Canal, fouling organisms must be able to survive an average of 5–8 hours in water of no detectable salinity (in Gatun and Miraflores Lakes, *cf.* Fig. 1). For stenohaline species this trip is apt to be fatal.

Menzies (1968) towed an assortment of marine animals through the Canal in an attempt to estimate the ability of fouling organisms to survive the sojourn in the fresh waters of Lakes Miraflores and Gatun (Fig. 1). He concluded that there was only a 'limited in-transit mortality as a result of the low salinity'. His experiment is worthy of further examination. A series of intertidal organisms was selected for his experiment, these being tied in cheese-cloth and towed behind a ship at speeds of up to 18 km per hr. At the upper speeds the animals skimmed and skipped over the surface of the water, so that Menzies estimates that they were totally submerged for only 3 hours of the total 8·5 hours required to complete the transit.

Obviously, organisms attached to the bottom of a ship would be subjected to a much longer period of freshwater immersion during a passage through the canal. Furthermore, by using intertidal organisms, Menzies selected animals which are exceptionally pre-adapted to euryhaline situations and so the results of his experiment are of limited value in extrapolating to typical fouling organisms. Also, Menzies scored his animals as alive or dead soon after completion of the transit, whereas time should have been allowed for recovery of the organisms, so as to evaluate delayed mortality. Menzies is fully aware of the limitation of his pilot experiment: he did not endeavour to perform the definitive research but merely to demonstrate that the subject was amenable to experimental verification.

Certainly, common fouling organisms such as intertidal barnacles can survive brief periods in fresh water, and Neal Powell, of the National Museum of Canada, believes that many Bryozoa can survive moderate exposures to fresh water. In a recent survey of the Bryozoa on the buoys in both the Pacific and Atlantic entrances to the Canal, he found a few species in common (Powell, personal communication).

Transport in Ballast

Many ships, particularly unladen ones, are required to take on sea-water ballast to improve their handling ability during transit. Although large volumes of water are involved (Chesher, 1968), the environment in most ballast tanks is remarkably inhospitable and frequently completely abiotic—particularly for the relatively sensitive planktonic organisms that are most likely to be taken into ballast systems (water samples from the few ballast tanks I have examined contained no living plankton). Anticorrosion paints that are used to protect these tanks are extremely toxic, and a few minutes contact with them is sufficient to kill most marine organisms. In addition, Chesher states that it takes about 6 hours to pass through the canal. A figure of eight hours would be closer to the average time. Furthermore, ships take on ballast water before arriving in Canal Zone waters and are prohibited by law from discharging ballast in Canal Zone waters. Consequently, the time that animals must live in ballast tanks in order to effect interoceanic transport is days or weeks in most cases. The probability of organisms being discharged in a hospitable environment is diminished by the great time and distances involved.

On the other hand, modern tankers are frequently equipped with stainless steel ballast tanks which are used exclusively for sea water, and these would seem to be more or less pre-adapted to the successful carrying of marine organisms from ocean to ocean. The present Panama Canal is, however, incapable of handling most of these modern larger tankers. The actual role of ballast transport through the present Canal is a subject that *could* be properly evaluated, and a thorough study should remove this area from speculation.

Examined in the proper perspective, we see that the transfer of marine organisms through the present Canal cannot be as extensive as is claimed by Sheffey when he writes (1968) 'Thus, all the small swimming and drifting marine life, that would be found in these

* Functional hermaphrodites would have an advantage as colonizers in this respect.

† This alters the sense of the term significantly from its common botanical connotation of any plant body which *can* propagate its taxon—Ed.

thousands of samples of sea water taken year in and year out since 1914, have made the trip across the isthmus in salt water in both directions. . . . It follows that a large portion of the small swimming, drifting, and clinging creatures on both sides of the isthmus have long been exposed to inoculations of the same category from the opposite ocean. It seems reasonable to conclude that a sea-level canal would create little or no threat to the lower links of the ocean food-chain'.

I, for one, find Sheffey's assurances unconvincing. The present canal is a highly restrictive filter.

RESULT OF BIOTIC INTERMIXING

A consequence of any sea-level canal would be a much less inhibited movement of species from one ocean to the other. Whether fauna and flora on either coast would become enriched, replaced, depauperate, extinct, or, in general, the ways in which interaction may occur between newly mingling species have been the source of some discussion. Briggs (1968, 1969), arguing strongly for a freshwater barrier to be included in any new canal, predicts the irrevocable extinction of several thousand unique species. 'For the tropical eastern Pacific, it is predicted that its fauna would be temporarily enriched but that the resulting competition would soon bring about a widespread extinction among the native species. The elimination of species would continue until the total number in the area returned to about its original level. *The fact that a large-scale extinction would take place seems inescapable*'.

Briggs's (1969) concept of numerical superiority of Atlantic fauna is based on a vertebrate : invertebrate ratio established for a small island in the Florida Keys. He then extrapolates this figure to the western Caribbean-eastern Pacific area on the basis of the 'relatively' well-known numbers of fish species. One may question the validity of this 1:13 vertebrate: invertebrate ratio for the western Caribbean, but its further extrapolation into the eastern Pacific is certainly unsubstantiated.

Can we really consider the invasion potential of an entire fauna or should individual phyletic groups be examined separately? Even if we accept Briggs's theory that the more diverse faunas will replace less diverse ones, this concept probably would not apply within those phyletic groups which are much more diverse in the Pacific than in the Atlantic. Present knowledge indicates that in many cases—*e.g.* porcellanid crabs, penaeid shrimps, sciaenid fishes, and perhaps the entire sandy-beach meiobenthos—the fauna is richer in the Pacific than in the Atlantic. Indeed, one would expect a richer intertidal fauna in the Pacific, with its much greater vertical niche differentiation (I. Rubinoff, 1968).

The question of whether species diversity is more important than physical pre-adaptations to a new environment must also be considered in evaluating a fauna's invasion potential. It is unlikely that any invading species will succeed in displacing a resident species through its entire range. Since most Panama Pacific species can be found north and south of 9°N latitude, they certainly can be expected to be adaptively superior to Atlantic invaders in at least some area along their range.

Briggs draws a parallel between linking the Atlantic and Pacific via a sea-level canal with the linkage of North and South America by the emergence of the isthmian land-bridge. The latter produced a temporary enrichment of South American mammalian fauna, but this was followed by rather large-scale extinctions of indigenous fauna. The evidence for blaming these extinctions on the invaders from the north is extremely circumstantial, and indeed current information indicates that the development of human societies may be more responsible for some of these extinctions than competition from any 4-legged mammals (Jelinek, 1967; Patterson & Pascual, 1968). Whether or not one agrees with Briggs's zoogeographic conclusions, his position, that there is a potential for inestimable effects which have not been appreciated or evaluated at the present time, deserves careful consideration.

At the American Association for the Advancement of Science symposium on biological aspects of a Sea-Level Canal, held in December 1969, a number of scientists expressed the views that in many systematic groups the populations were so similar that competition was unlikely. But however similar these groups may appear, the presence of some differences indicate that evolution has taken place during the period of isolation. Therefore, by simple application of the Gaussian principle of competitive exclusion, we see that the two populations cannot conceivably come together without competing in some way. It is impossible for two different organisms (however slightly they may differ) to utilize a resource with equal efficiency. The ways that this competition will be exhibited may be subtle and not necessarily detrimental. But to claim that no competition or genetic interaction will occur, on the basis of morphological similarity or even identity, is blatantly ignoring basic ecological and evolutionary principles.

PREDICTABILITY FROM PRE-CANAL RESEARCH

Much has been written, and there has been much discussion, on possible effects of a sea-level canal. The sceptical view has been expressed that our ecological sophistication is insufficient to permit the prediction or identification of the problem organisms, and therefore that any such effort would be wasted.

I believe that many biotic interactions resulting from a sea-level canal could be more or less accurately predicted through a comprehensive pre-canal research programme. For example it is possible to determine some potential genetic interactions between allopatric populations coming from different regions in controlled laboratory experiments (e.g. *Bathygobius*—R. W. Rubinoff, in prep.). It is also possible to assay the colonizing ability of potential interoceanic invaders by testing their reactions to potential predators and prey (e.g. *Pelamis platurus*—I. Rubinoff & C. Kropach, in prep.). Examination of the vulnerability of organisms to potential parasites is also amenable to laboratory investigation.

It is not intended to design and describe a sea-level canal biological programme here, but rather to point out areas of interaction for which probability limits can be established, in advance, on the basis of controlled experiments. However, I believe that if sufficient programme support is available, the biological effects of a sea-level canal can be put on a firmer basis of scientific prediction. Recent developments in experimental zoogeography (Wilson & Simberloff, 1969; Simberloff & Wilson, 1969; Wilson, in press) illustrate methods of evaluating similar ecological problems by controlled experiments. If our ecological knowledge does not become sufficiently sophisticated to predict the biological effects, then the new canal certainly should include a biotic barrier to be maintained until we are confident there will be no untoward effects.

In a time of great concern for problems of environmental exploitation, we have yet to witness a tangible solution of any of these situations *on other than a local basis*. The proposed sea-level canal is a challenge —one that can be met feasibly by comprehensive study and careful non-emotional planning. Let us anticipate the problems and not have to rectify irresponsible mistakes.

Fortunately, the National Academy of Sciences of the United States has appointed a committee to evaluate the ecological problems of the proposed sea-level canal, and to recommend study strategies. Hopefully, their recommendations for further studies will be translated (in adequate time and with sufficient funds) into a comprehensive analysis of ecological consequences as well as a thorough inventory of extant Central American marine flora and fauna.

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