HELGOLÄNDER MEERESUNTERSUCHUNGEN
Helgoländer Meeresunters. 33, 662–673 (1980)

The problem of introduced species in management and mitigation

J. W. Hedgpeth

5660 Montecito Avenue; Santa Rosa, California 95404, USA

ABSTRACT: One hundred years ago the striped bass *Morone saxatilis* was introduced in the San Francisco Bay estuarine system from the east coast of the United States. It was part of our national policy at the time to transplant all potentially useful species everywhere else. The policy was facilitated by completion of the transcontinental railroad in 1869. As a result, the present ichthyofauna of the San Francisco Bay area is largely alien. Introduction of eastern oysters *Crassostrea virginica* resulted in the inadvertent introduction of many species of invertebrates. Identification of these introduced species was not realized as a problem until recently, and no one knows how many exotic species there are. In other parts of the world there are examples of similar introductions, e.g. *Crepidula fornicata* and *Rhithropanopeus harrisi* in Europe. Although it is now the policy to frown upon and prohibit introductions, they cannot be prevented and the process still continues, as witnessed by the examples of *Elminius modestus* in Europe and *Palaemon macrodactylus* in California. In the USA the recently developed idea of "mitigation," the artificial replacement of disturbed or destroyed areas by development of quasi-natural areas in compensation, has been accompanied, at the hands of inexperienced practitioners, by potentially dangerous introductions of exotic species. The assumption, for example, that cordgrass *(Spartina)* should be equally beneficial everywhere in the world has led to the disrupting introduction of potentially hybridizing species in New Zealand and aggressive immigrants in Oregon marshes. This situation calls for more sophisticated understanding of the role of introduced species in natural aquatic ecosystems, and a higher degree of competence in systematic biology.

INTRODUCTION OF EXOTIC SPECIES

A hundred years ago, in July of 1879, 132 striped bass *Morone saxatilis* from New Jersey were planted in San Francisco Bay. This planting occurred during the height of hydraulic mining in the Sierra Nevada with its resulting heavy silt loads in the rivers and the bay, and about 15 years after the greatest floods on record had inundated much of California's Central Valley and turned the bay temporarily into a freshwater lake; it took hold almost immediately. Shad *(Alosa sapidissima)* had been planted a few years before, and many other species of fish from the eastern seaboard and the streams of the middle part of North America were planted in San Francisco Bay. As a result, the fish fauna, which formerly consisted mostly of salmonids, viviparous perch (Embiotocidae) and various cyprinids and suckers (Catastomidae) was completely altered. Various freshwater basses, sunfish and others (Centrarchidae), catfish and all sorts of smaller fry (some of these for mosquito control) now flourish in the waters of San Francisco Bay. The striped bass became commercially important, but in 1935 it was restricted for sport fishing only as it became apparent that the stock could not support both commercial and recreational

 0017-9957/80/0033/0662/$ 02.00

fishing. Today, however, it is suffering a significant decline, primarily because of the alterations in California's water system which involve massive diversions of water from the bay to irrigate the arid lands of the southern part of the Central Valley and maintain the monstrous sewers of Los Angeles. In addition to the diversions, there are great losses of eggs and young fish through the pumps that supply the enormous aqueducts (Chadwick et al., 1977). At the same time this introduced stock in California is declining, the parent stock on the east coast, especially in Chesapeake Bay, is decreasing rapidly. In large part this may be due to the unrestricted resort fishing, without bag limits. So far, factors which may be common to both populations, such as pesticide pollution, industrial diversions, etc., have not been investigated to ascertain if there are some causes in common for diminishing stocks on both sides of the continent.

Most of the introductions of fish a hundred years ago were results of the policy of the United States Fish Commission to populate the waters of the United States with as many useful or valuable food species as possible. The effort was made to transplant fishes from the Pacific coast to the eastern seaboard, especially the salmons, including various members of the genus *Oncorhynchus* to streams of the east coast, and even to the lowland streams of Texas. Rainbow trout *(Salmo gairdneri)* and chinook salmon (*Oncorhynchus tschawytscha)* were successfully planted in New Zealand streams, but did not succeed in Chile.

In addition to this effort to increase the supply of food fish, attempts were made to establish the eastern oyster *Crassostrea virginica* in San Francisco Bay as soon as it was feasible to transport them across the continent after completion of the transcontinental railroad in 1869. With this effort there also began, apparently, the steady influx of exotic invertebrates hitchhiking, so to speak, among the oysters. Many of the species involved were not recognized at first as introduced species, and some of them may still not be. Lobsters were introduced in the 1870's, but they were never heard of again after being released into the Pacific Ocean at the Golden Gate. There is still interest in establishing *Homarus* in Pacific waters, but the conditions do not seem right for it, and such an introduction is being discouraged in the warmer southern waters because of possible competition with the native species of *Panulirus.* Carlton (1975), who has been studying the records of introduced species along the Pacific coast, estimates that there may be as many as 150 or 200 species of introduced invertebrates. Introductions continue despite the fact that deliberate introduction of exotic species is now discouraged since some of them may be pests of commercially valuable species, such as oyster drills. The little eastern mud crab *Rhithropanopeus harrisi* was first noticed in San Francisco Bay in the late 1930's (Jones, 1940) and an oriental shrimp *Palaemon macrodactylus* came to light sometime after 1950 (Newman, 1963). A freshwater clam from the Phillipines was brought in, probably as bait at some time or another, and is now a pest in the aqueducts, where it accumulates sediment and reduces flow in the canals. The latest addition to the fauna of San Francisco Bay appears to be a Japanese goby, *Acanthogobius flavimanus.*

Accidental and inadvertent introductions of marine invertebrates into European waters began early, perhaps with the beginning of transoceanic voyages as early as the 15th century. For many introductions we have no record, and one, the small mud crab of northeastern America, *Rhithropanopeus harrisi,* was not recognized as an immigrant in Europe until the 1930's. In Europe this crab was originally known as *Heteropanope tridentatus,* and some carcinologists wonder if it is really a native American species or an amphi-atlantic species that was described first from North American specimens. However, its recent expansion to the Black Sea and the Baltic Sea (Pautsch & Lawinski, 1966) would suggest that it may be an immigrant species finally taking hold. It has even reached the Caspian Sea. *R. harrisi* is, as far as we can tell at this time, an inoffensive introduction, unlike the Chinese mitten crab, *Eriocheir sinensis*, whose habit of burrowing in dikes and canals has caused maintenance problems. *E. sinensis* is believed to have made its way from China in the water tanks of ships (Hoestlandt, 1948); it is a species that lives in fresh water but reproduces in the sea. It was first noticed about 1912 in the region of the lower Elbe and Weser (Germany) and has spread south into France and north into the Gulf of Finland.

One of the most important introductions into European waters is that of the American Atlantic blue crab, *Callinectes sapidus*. This is a major commercial species of the Atlantic coastal bays on the United States. It was first noticed in Europe about 1901 (Williams, 1974), but there is no record or indication of the method of how the species, and other decapods with several planktonic larval stages, made their way across the ocean. *Callinectes sapidus* has been reported at various localities from Denmark to the Bay of Biscay, the Mediterranean, Adriatic and Aegaean Seas (Holthuis, 1969). Some of these records are probably of isolated occurrence rather than established populations, but the immigrant populations of the blue crab in the eastern Mediterranean, especially along the coast of Israel, have become of economic significance in the fishery (Holthuis & Gottlieb, 1955, 1958). There is, incidentally, no record as far as I know of any attempt to introduce *Callinectes sapidus* into San Francisco Bay. If the attempt was made, its failure would indicate that water temperatures are too low for this species during its reproductive period; *C. sapidus* requires temperatures of 20 °C and above for reproduction (Norse, 1977).

While one might speculate that the emigration into Europe from America by *Callinectes sapidus* might possibly have been achieved by the straying of gravid females from America (which does not, however, explain the colonization of the Mediterranean), the spectacular appearance of a New Zealand barnacle, *Elminius modestus*, in Europe in 1943 must have been managed by unwitting human intervention. Voyage times from New Zealand had not changed significantly for a hundred years, and it appears that the sudden appearance of this barnacle on British shores may have been related to the increased volume of shipping during World War II, and consequently increased numbers of barnacles, thus providing a "critical mass" that enabled establishment of the species so far from home (Hedgpeth, 1957a). Six species of barnacles not previously recorded in New Zealand were identified among the fouling organisms on an oil platform constructed in Osaka Japan and floated to New Zealand (Foster & Willan, 1979).

Many introductions of American invertebrates into European waters can be attributed to the introduction of oysters, as in San Francisco Bay. The species involved are for the most part associated with oysters as commensals or pests, but almost any species somehow associated with oysters may have been transplanted. Some of these are illustrated in Figure 1. Kornicker (1975) has recognized the American ostracod *Sarsiella zostericola* as one of the species transferred with oysters, and states that "recognition of these species is necessary for correct ecological and zoogeographical interpretations." The economonic implications of the introduction of the associated slipper limpet *Crepidula fornicata* have long been recognized. This species tends to settle on oysters in

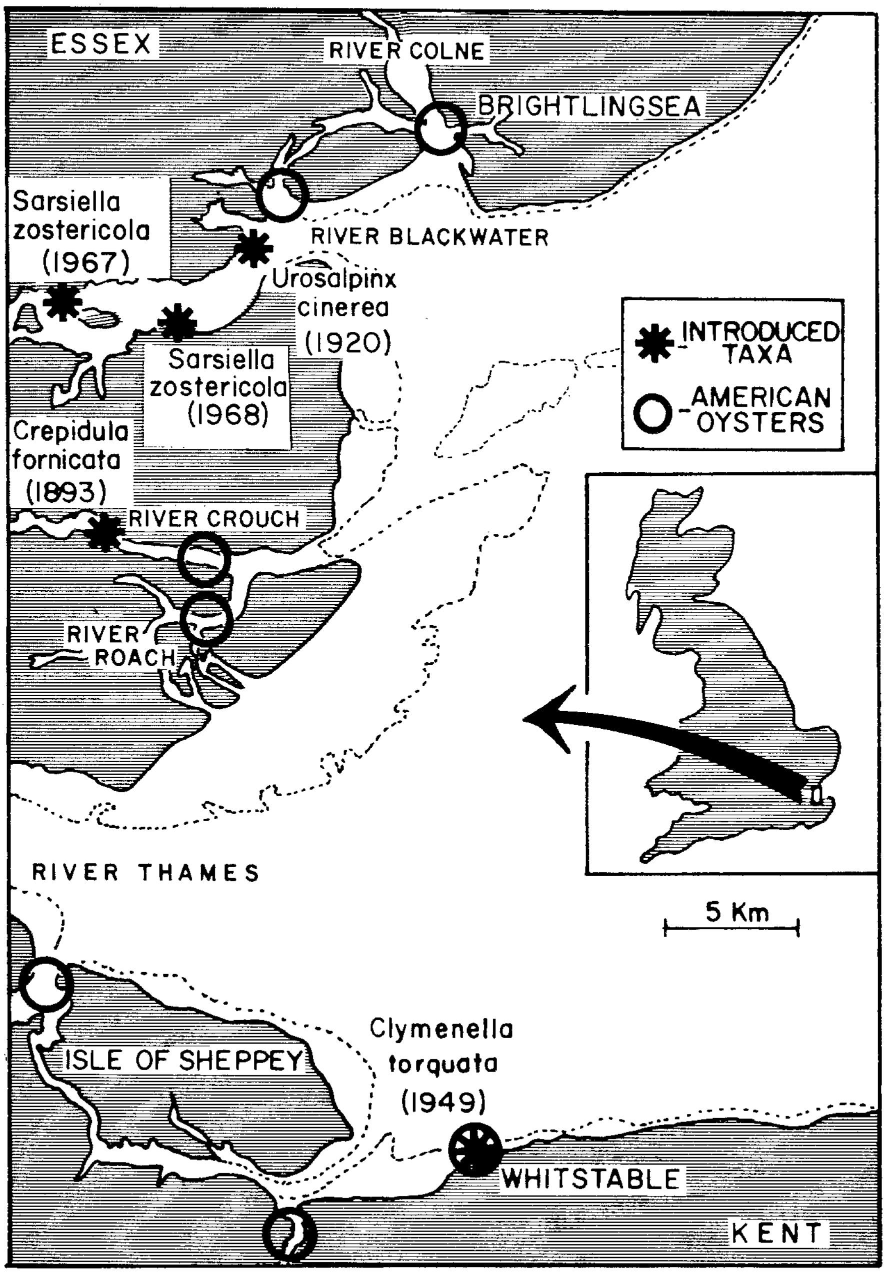

Fig. 1. Southeast coast of England (Essex and Kent) showing areas where oysters *Crassostrea virginica* from the USA have been reset and the localities and dates of initial appearance of other species introduced with the oysters (after Kornicker, 1975)

significant numbers, and since it has similar feeding habits, may constitute active competition for food with the oysters. The oyster drill *Urosalpinx cinerea* like the Japanese oyster drill on the Pacific coast, preys upon young oysters and may be a serious pest.

An exotic eel grass, *Zostera nolti*, has established itself in Willapa Bay, Washington. This species, which may have come from Japan as seed on oysters, is finding its place on the bare intertidal surface between the native *Z. marina* and *Salicornia*. It may become troublesome in time, pre-empting space where the principal agent of primary productivity has been sessile diatoms with a rich secondary production of various worms, detritus-feeding snails and small crustaceans.

It is to be noted that our concern in these various introductions has not been for the natural community into which we have introduced them, but for the production of the oysters transferred from place to place. The significance of introduction of exotic species is still not completely understood, but often the side effects or coincident introductions of other species of potential harm to the environment into which they are introduced have been ignored. However, the reaction and concern for introduction of seaweeds discussed below indicates that we are beginning to realize that introductions of exotic species are not an unmixed blessing.

Seaweeds are important sources of iodine and alginate, an important plant additive and inert component of drugs. The Chinese have depended on *Laminaria* for iodine for 1500 years (Neushul, 1978), although it does not occur naturally on the Chinese coasts. In the last 20 years or so the Chinese have undertaken culture of *Laminaria* (using sterile stock) in their own waters with such success that the yield compares with that of the *Macrocystis* harvest on the California coast, and they export it to Japan (Cheng, 1969; Tseng, 1975). A few years ago the possibility of transplanting the giant kelp *Macrocystis pyrifera* into European waters on the Brittany coast was considered (Perez, 1972). Although Dr. W. North, who has had considerable experience with experimental planting of this species in its home waters, was of the opinion that it could not be naturalized in Europe, opposition to the idea was vehement; Russell (1978), for example, urged that introduction of *Macrocystis* "should be resisted." Evidently this opposition was inspired in part by the example of the Japanese *Sargassum muticum*, which has become naturalized in British Columbia and the Channel Islands off the California mainland, and has recently appeared around the Isle of Wight and is soon expected on the British mainland.

Domestication of seaweed, especially the large kelps, in the sense of cultivating crops of known genetic composition, appears to be on the way (Neushul, 1978; Sanbonsuga & Neushul, 1978). These workers have developed sterile hybrids of *Macrocystis* and *Pelagophycus*; such hybrids if commercially successful would – or should – calm some of the opposition to domestication of seaweeds in extraterritorial waters. As M. Neushul remarks (in lit.) the use of sterile hybrids "would be a very safe way to enhance macroalgal mariculture." However, according to Dr. W. North (in lit.) the French had planned to use sterile plants (not hybrids), but this did not reassure critics of the scheme.

UNPLANNED IMPACTS

Another category of introductions is that resulting from man's remodeling of the earth to suit his needs. The most famous and best known example is of course the Suez

Canal. The first canal between the Mediterranean and Red Seas was constructed in ancient times from the delta of the Nile to the Gulf of Suez; after various periods of disuse it was finally abandoned in the 8th century A.D. This canal was maintained by fresh water from the Nile, and consequently there may have been little interchange of marine fauna between the two seas. The modern canal, completed in 1869, is a hundred miles long. Until recently the hypersaline Bitter Lakes and the fresh waters of the Nile were effective filters against faunal interchange (Hedgpeth, 1957b); recently, however, the salt deposits of the Bitter Lakes have been reduced and the inflow of fresh water into the delta of the Nile has been reduced by construction of the Aswan Dam, and migrations from the Red Sea have increased (Thorson, 1971a, b).

Among the more spectacular migrations in the last two decades has been that of the lizard fish *Saurida undosquamis* which first appeared in the Mediterranean in 1952. The population increased rapidly and by 1955/56 it had become one of the important commercial fishes, accounting for 11 % of the total fish landings. The fishery for lizard fish increased until 1959, while at the same time that for hake *Merluccius merluccius* declined. Ben-Yami & Glaser (1974) have associated this population surge with a complex interplay of physical and ecological factors, though they do not consider the changes in flow and silt load of the Nile since construction of the Aswan Dam. Undoubtedly a similar interplay of factors accompanied the introduction of striped bass in San Francisco Bay in 1879, but we lack the necessary information, especially on interacting species.

The Panama Canal is not an open channel like the present Suez Canal, but an elaborate system of locks that are operated by fresh water from Gatun Lake (85 feet above sea level). This arrangement prevents the passage of all but a few hardy species, mostly associated with fouling growth on vessels. The canal is now obsolete for the volume of traffic and the enormous size of modern oil tankers, not only because of the width of the locks, but because the fresh water supply from Gatun Lake is inadequate, because of the small catchment area, to operate the locks frequently enough. For some years there has been discussion of a new canal at sea level, perhaps to the south of the present canal. The mean tidal range on the Atlantic side of the Isthmus is about a foot whereas on the Pacific side it is 12.6 feet, and the mean sea level is 30 cm higher on the Pacific side. These differences will require locks, since they would set up currents of at least 2 knots in an open canal; large ships cannot be managed in such currents in a narrow canal.

The prospect of a sea-level canal of some sort across the Isthmus of Panama has stimulated discussion about possible migration of organisms from one ocean to the other. Briggs (1968, 1969) views this prospect with considerable alarm, predicting a mass migration of Pacific species, including *Acanthaster planci* and poisonous sea snakes *(Pelamis platurus)* into the Atlantic with resultant competition which would "result in the irrevocable loss of not one or two but hundreds or even thousands of species" (Briggs, 1974). The long geological history of interchange between the oceans during periods when the continents were not joined by the isthmus, with the resulting development of many geminate pairs of species, suggests that Briggs' predictions are on the drastic side.

The concern for the biological effects of a sea-level canal across the Isthmus of Panama together with the formidable engineering problems of a sea-level project have resulted in a tacit turn to other possible alternatives. It has been suggested, for example, that the problem of operation of the locks might be solved by converting Gatun Lake to a salt lake by pumping sea water back to operate the locks. This would of course eliminate the freshwater barrier to migration, which so far has prevented all but a few euryhaline species from passing from one ocean to the other (McCosker and Dawson, 1975). Under the present system, with Gatun Lake consituting a freshwater barrier, some highly euryhaline fouling species have passed through often (Menzies, 1968). The proposal to convert the entire canal system to sea water without any consideration of possible admixtures of Pacific and Atlantic biota, is, as Newman (1972) states: "the idea of connecting the tropical American marine biotas by a seaway without an effective antibiotic barrier is presently indefensible." The concern over the proposal to alter the present regime of the Panama Canal in one way or another has generated a modest volume of informed scientific opinion, most of it unfavorable (Rubinoff, 1968, 1970; Sheffey, 1968; Springer, 1973). The most recent development in the low-level canal scheme (March, 1980) is discussions between Japanese financial and development interests and Panamanian officials about constructing such a canal, without locks, west of the existing canal. No consideration of environmental impact is apparent in the reports of these discussions.

For some species a canal with its salinity differences and fluctuating current patterns acts as a "selective barrier" as in the case of the Suez Canal for calanoid copepods and larval decapods (Kimor, 1971). The Bosphorus acts in a similar manner as a natural filter restricting the penetration of Mediterranean forms to the Black Sea, although in this case the differences in salinity and the azoic below about 200 m are significant factors in the process. Some elements of the Black Sea fauna are considered to be relicts of a "pre-Bosphorous" period (Caspers, 1968).

The action of dispersal or migration through a canal or narrow passage involves, in addition to the primary barrier of the narrow passage, the nature of the sediments, hydrological gradients and biological factors.

MITIGATION

Mitigation, the idea that unavoidable or irreparable damage to an environment may be compensated for by undertaking some ecological amelioration somewhere else as replacement for the damage, is a recent concept in environmental management. It seems to owe its inspiration, in part at least, to the practice of stabilizing spoil banks accumulating from harbor and channel dredgings with marsh plants and ultimately establishing marshes on these sites. This procedure was developed by the United States Army Corps of Engineers, charged with developing harbors and maintaining channels and waterways. This necessity has been made into a virtue and the emphasis now seems to be on "habitat development" rather than stabilization of freshly dredged material. The procedure is described in some detail in the Corps of Engineers Technical Report DS-78-16 (United States, 1978).

The concept of mitigation, as it is now developing, however, does not mean that what must be damaged or destroyed has to be replaced exactly, but that some equivalent effort be put into establishing a new environment, or that donation or dedication of some other property will be accepted as a quid pro quo. Thus a logging company, in exchange for cutting timber on a controversial site, might dedicate some parcel cut over years before and now supporting a good second growth, or some property inaccessible to its equipment as "mitigation" for the damage to an environment of ecological or esthetic significance. In practice this approach can lead to incongruous compromises that satisfy no one, an exercise not in applied ecology but in misapplied ecology. A particularly grievous example of this sort of "mitigation" is the opening up of an old cow pasture to the tidal waters of Humboldt Bay, California, in compensation for the destruction of Woodley Island, an attractive feature of the downtown waterfront area of Eureka (the city on Humboldt Bay) because of its growth of trees and aggregations of birds, especially egrets, for a marina for fishing boats, with parking lots, gaudy hot dog stands, warehouses and the like. All of this to confront a city beautification scheme involving redesign of streets, and rehabilitation of Victorian architecture intended to inspire both citizens and tourists with pleasing vistas. Man has since time immemorial improved upon nature to his own taste, and perhaps has as often been guilty of such jarring inconsistencies, but the concept of mitigation gives sanction to such misdeeds in the name of environmental quality. It is a notion that should not be kindly received, and is particularly dangerous because it may encourage introductions of aggressive plants.

With respect to management of coastal regions, the most dangerous plants involved in such mitigation schemes are the species of cordgrass *Spartina*. Here we are dealing not only with deliberate or accidental introductions, but with what appears to be a spontaneous hybrid. Cordgrass is most characteristically found on salt marshlands of the eastern United States and Gulf coasts. It does not occur naturally in New Zealand, where it has been introduced, or along the northwest coast of the United States and Canada, although it has been recently introduced in at least one place in Oregon. It is not a major marshland plant in most locations of California except the bays south of Los Angeles. *Spartina foliolosa*, the species occurring in San Francisco Bay and northwards, may be a souvenir of Spanish colonial times, when the principal forage plants of the California lowlands and hillsides, the wild oat *Avena fatua*, the bur clover *Medicago hispida* and the filaree *Erodium moschatum* and *E. circutatium* along with the yellow mustard *Brassica campestris* (and several other species of mustard) were introduced from Spain.

Spartina foliolosa in San Francisco Bay does not seem to be as aggressive a species as those of eastern marshlands; certainly the evidence suggests it is more subject to control by hydrographic conditions than by ecological interaction with other species. It also seems to be less productive than *Spartina* species of the southeast Atlantic marshes, perhaps more similar in this respect to the *Spartina* of English marshes (Mahall & Park, 1976). Net production of *Spartina alterniflora* may be as much as 17.8 tons per acre under certain conditions as compared with 14.7 tons per acre for Hawaiian sugar cane and 5.7 for an American corn field (Odum, 1974). Suggestions that this production may in turn be a significant part of the nutrient budgets of coastal waters (as distinguished from that recycled in the marsh itself) are evidently somewhat optimistic (Haines, 1975).

On the Pacific coast, especially in California, where it is obvious that marshlands (or in the broader sense "wetlands") because of their comparatively small size are insignificant contributors to the oceanic fisheries of coastal waters, it is suggested that they are unnecessary for protection of fisheries and that therefore the best use of them is to convert them to boat harbors, especially for recreational boats. This attitude betrays ignorance of the function of wetlands within the bay systems, especially of bare tidal flats. The waddens of the North Sea and the mud flats of San Francisco Bay are both significant regions for secondary productivity as demonstrated by the work of Wolff (1977) and Nichols (1977) and it seems obvious that injudicious planting of *Spartina*, especially of introduced species, should be avoided as a potential danger to ecosystems of the tidal flats.

The British species is *Spartina maritima*. According to the summary by Hubbard (1965), the American *S. alterniflora* was first collected in English marshes in 1829, but it was probably present several years before that time. As early as 1870 a hybrid between these species (not then recognized as such) was discovered and named *S. townsendi*. The occurrence and spread of this hybrid has been documented for Poole Harbour where it was collected in 1899, but it was apparently present at least as early as 1887. In any event, the plant spread throughout Poole Harbour and its obvious success as a colonizer of tidal flats and protection against erosion and an agent for land reclamation led to its introduction in many other parts of the world (Goodman et al., 1959). During the late 1920's *S. townsendi* was introduced in Germany, Denmark and remoter localities, including Australia and New Zealand, where it was welcomed at first as a useful plant (Harbord, 1949). However, its rapid spread in the Avon-Heathcote estuary near Christchurch has endangered areas utilized by birds and threatens to reduce the water surface area of the bay, and it has been declared a "noxious weed" in New Zealand (G. A. Knox, in lit.).

In a number of places in England its aggressive growth has required remedial action. In other regions, after apparent success, it has started to "die back" which suggests that deliberate reclamation projects utilizing this plant may have a dubious future (Goodman et al., 1959).

The hybrid *Spartina* is obviously not an unmixed blessing, and may at best be an unreliable plant for reclamation purposes in the long run when it is not a dangerously aggressive immigrant. Another eastern species, *Spartina patens*, was introduced at the mouth of the Siuslaw Island in Oregon, where it is apparently replacing the native *Carex lyngbyia* (Dr. P. P. Rudy, personal communication). This is not a hybrid species, and may in the long run turn out to be a more serious introduction, for even if it should die back, disruption of the native flora and its associated faunal complex have already occurred. In San Francisco Bay one not too well-informed consultant planted both *Spartina maritima* and *S. alterniflora* as part of a mud flat stabilization project, thus establishing the potential for fresh hybridization to produce *S. townsendi* (Dr. H. T. Harvey, in lit.). It is my understanding that some effort has been made to uproot the offending introductions; it is earnestly to be hoped that San Francisco Bay, with all its present troubles, will not have to endure a repetition of the English and New Zealand experiences.

CONCLUDING REMARKS

In general our experience with introducing exotic species of marine and estuarine animals and plants has been that those we wanted to establish in a new environment have not succeeded, while species that are harmful to native species or ecologically disrupting have succeeded all too well. Oysters may grow well in strange waters, but they usually do not reproduce and require constant imports of fresh stock, or must be sustained by hatchery-reared larvae. Natural reproduction has occurred spontaneously with Japanese oysters in British Columbia, but this is an exception, and it was not planned. All attempts to establish Atlantic lobsters in the northeastern Pacific have failed. The spectacular success with shad, striped bass and many other fishes into San Francisco Bay and its fresh water tributaries may be more an indication of a disturbed estuarine environment with available niches for colonization than of introduction into an integrated ecosystem in a steady state condition. The spontaneous acclimation of the blue crab *Callinectes sapidus* is a happy example of a valuable species that succeeded without apparent human intervention. Here again, however, it may represent colonization of an unoccupied niche.

In most of these examples of intentional or accidental introductions we have no clear evidence of the effects of the introduction on other species, for the most part because we have no adequate baselines of pre-introduction conditions for evaluating the impact of the introductions. This is particularly true for the case of San Francisco Bay. The effects of the introduction of plants like *Spartina* and *Zostera* on sedimentation and consequent alteration of hydrographic regimes are almost immediately apparent, but some introduced invertebrates may survive for many years after their introduction before producing obvious populations. *Eriocheir sinensis* and *Rhithropanopeus harrisi* appear to be examples of this in European waters.

In Europe, where the flora and fauna are fairly well known, the presence of introduced species may be noticed almost immediately, or at least perhaps within a decade of introduction. In regions where the biota is not adequately known, introductions may be unnoticed for many years. Of course it may be said, in view of the number of cosmopolitan, pantropical, circumboreal, etc., species and the catastrophes of sea-level changes, volcanic upsets, shifting rivers and the like, that man's activities are insignificant contributions to long-term natural processes influencing distribution. Perhaps so, but at the same time premature introductions without the accompaniment of such physical changes may accelerate changes in ecosystems that will ultimately affect man's dependence on the productivity of coastal waters. Provoking Mother Nature is a risky business.

Detection of new additions to marine and estuarine biota and of the changes they may precipitate in the endemic biota calls for a high level of surveillance and competence in systematic biology and an adequate staff in museums and conservation agencies to review collections and detect alien species. Adequate and accurate species lists may well be the most important data bases for implementation of all our environmental concerns, as Slobodkin et al. (1980) suggest, for without a clear knowledge of what we are dealing with, models and elaborate food web diagrams have little meaning. A vigorous, aggressive migrant into the system may invalidate our concepts of the status quo and require reconsiderations of management and protective procedures.

LITERATURE CITED

Ben-Yami, M. & Glaser, T., 1974. The invasion of *Saurida undosquamis* (Richardson) into the Levant Basin – an example of biological effect of interoceanic canals. – Fish. Bull. U. S. *72*, 359–373.

Briggs, J. C., 1968. Panama's sea-level canal. – Science, N.Y. *169*, 511–513.

Briggs, J. C., 1969. The sea-level Panama canal: potential biological catastrophe. – Bioscience *19*, 44–47.

Briggs, J. C., 1974. Marine zoogeography. McGraw Hill, New York, 475 pp.

Carlton, J. T., 1975. Introduced intertidal invertebrates. In: Light's manual: Intertidal invertebrates of the central California coast. Ed. by R. I. Smith & J. T. Carlton. Univ. of California Press, Berkeley, 17–25.

Caspers, H., 1968. La macrofaune benthique du Bosphore et les problèmes de l'infiltration des éléments méditerranéens dans la mer Noire. – Rapp. P.-v. Réun. Commn int. Explor. scient. Mer Méditerr. *19*, 107–115.

Chadwick, H. K., Stevens, D. E. & Miller, L. W., 1977. Some factors regulating the striped bass population in the Sacramento-San Joaquin estuary, California. In: Proceedings of the conference on assessing the effects of power-plant-induced mortality on fish populations. Ed. by W. Van Winkle. Pergamon Press, Oxford, 17–35.

Cheng, T. H., 1969. Production of kelp – a major asset in China's exploitation of the sea. – Econ. Bot. *23*, 424–444.

Foster, B. A. & Willan, R. C., 1979. Foreign barnacles transported to New Zealand on an oil platform. – N. Z. J. mar. Freshw. Res. *13*, 143–149.

Goodman, P. J., Braybrooks, E. M. & Lambert, J. M., 1959. Investigations into "Die-back" in *Spartina townsendii* agg. I. The present status of *Spartina townsendii* in Britain. – J. Ecol. *47*, 651–677.

Haines, E. B., 1975. Nutrient inputs to the coastal zone: the Georgia and Carolina shelf. – Estuar. Res. *1*, 303–324.

Harbord, W. L., 1949. *Spartina townsendii*: A valuable grass on tidal mud flats. N. Z. J. Agr. *78*, 507–508.

Hedgpeth, J. W., 1957a. Marine biogeography. In: Treatise on marine ecology and paleoecology. Ed. by J. W. Hedgpeth. Geol. Soc. Am., New York *1*, 359–382.

Hedgpeth, J. W., 1957b. Estuaries and lagoons. In: Treatise on marine ecology and paleoecology. Ed. by J. W. Hedgpeth. Geol. Soc. Am., New York *1*, 673–749.

Hoestlandt, H., 1948. Recherches sur la biologie de l'*Eriocheir sinensis* en France (Crustacé Brachyoure). – Annls Inst. océanogr., Monaco N.S. *24*, 1–116.

Holthuis, L. B., 1969. Enkele interessante nederlandse Crustacea. – Zool. Bijdr. *11*, 34–48.

Holthuis, L. B. & Gottlieb, E., 1955. The occurrence of the American Blue Crab, *Callinectes sapidus* Rathbun, in Israel waters. – Bull. Res. Coun. Israel *5* (B), 154–156.

Holthuis, L. B. & Gottlieb, E., 1958. An annotated list of the decapod Crustacea of the Mediterranean coast of Israel, with an appendix listing the Decapoda of the eastern Mediterranean. – Bull. Res. Coun. Israel *7* (B), 1–126.

Hubbard, J. C. E., 1965. *Spartina* marshes in southern England. VI. Pattern of invasion in Poole Harbour. – J. Ecol. *53*, 799–813.

Jones, L. L., 1940. An introduction of an Atlantic crab into San Francisco Bay. In: Proceedings of the sixth Pacific Science Congress of the Pacific Science Association. Univ. of California Press, Berkeley *3*, 485–486.

Kimor, B., 1971. The Suez Canal as a link and barrier in the migration of plankton organisms. – Proc. Joint Oceanogr. Assembly Tokyo *1970*, 480.

Kornicker, L. S., 1975. Spread of ostracodes to exotic environs on transplanted oysters. – Bull. Am. Paleont. *65* (282), 129–139.

McCosker, J. E. & Dawson, C. E., 1975. Biotic passage through the Panama Canal, with particular references to fishes. – Mar. Biol. *30*, 343–351.

Mahall, B. E. & Park, R. B., 1976. The ecotone between *Spartina foliolosa* Trin. and *Salicornia virginica* L. in salt marshes of northern San Francisco Bay. I. Biomass and production. – J. Ecol. *64*, 421–433.

Menzies, R. J., 1968. Transport of marine life between oceans through the Panama Canal. – Nature, Lond. *220*, 802–803.

Neushul, M., 1978. The domestication of the giant kelp, *Macrocystis*, as a marine plant biomass producer. In: The marine plant biomass of the Pacific northwest coast. Ed. by R. Krauss. Oregon State University Press, Corvallis, 163–181.

Newman, W. A., 1963. On the introduction of an edible oriental shrimp (Caridea: Palaemonidae) to San Francisco Bay. – Crustaceana *5*, 118–132.

Newman, W. A., 1972. The National Academy of Science Committee on the ecology of the interoceanic canal. – Bull. biol. Soc. Wash. *1972*, 247–259.

Nichols, F. H., 1977. Infaunal biomass and production on a mudflat, San Francisco Bay, California. In: Ecology of marine benthos. Ed. by B. C. Coull. Univ. of South Carolina Press, Columbia , 339–357. (Belle W. Baruch Library in Marine Science. Nr 6.)

Norse, E. A., 1977. Aspects of the zoogeographic distribution of *Callinectes* (Brachyura: Portunidae). – Bull. mar. Sci. *27*, 440–447.

Odum, E. P., 1974. Introduction. Guale, the Golden coast of Georgia. Friends of the Earth, San Francisco, 18–28.

Pautsch, F. & Lawinski, L., 1966. Some remarks on the migration and biology of the crab, *Rhithropanopeus harrisi* (Gould) as a new component of the European brackish water fauna. Abstr., int. oceanogr. Congr., Moscow *2*, 280–281.

Perez, R., 1972. Opportunité de l'implantation de l'algue *Macrodystis pirifera* (sic) sur les côtes bretonnes. – Sci. Pêche *216*, 1–12.

Rubinoff, I., 1968. Central American sea-level canal: possible biological effects. – Science, N. Y. *161*, 857–861.

Rubinoff, I., 1970. The sea-level canal controversy. – Biol. Conserv. *3*, 33–36.

Russell, F. S., 1978. Biology and human affairs. – Adv. mar. Biol. *15*, 233–248.

Sanbonsuga, Y & Neushul, M., 1978. Hybridization of *Macrocystis* (Phaeophyta) with other float-bearing kelps. – J. Phycol. *14*, 214–224.

Sheffey, J. P., 1968. When Caribbean and Pacific waters mix. – Science, N. Y. *162*, 1329.

Slobodkin, L. B., Botkin, D., Maguire, B., Moore, B., III & Morowitz, H., 1980. The epistemology of ecological analysis. Proc. biennial estuar. Res. Conf. *5*. (In Press.)

Springer, V. G., 1973. Resolution on the Panama Canal. – Science, N. Y. *182*, 336.

Thorson, G., 1971a. Animal migrations through the Suez Canal in the past, recent years and the future (A preliminary report). – Vie Milieu *22*, 841–846.

Thorson, G., 1971b. Life in the sea. McGraw Hill, New York, 256 pp.

Tseng, C. K., 1975. The breeding of new varieties of Hadai (*Laminaria japonica* Aresch.) with high production and high iodine content. – Proc. int. Ocean Dev. Conf., Tokyo. *3*, 100–131.

Williams, A. B., 1974. The swimming crabs of the genus *Callinectes* (Decapoda: Portunidae). – Fish. Bull. U. S. *72*, 685–798.

Wolff, W. J., 1977. A benthic food budget for the Grevelingen Estuary, the Netherlands, and a consideration of the mechanisms causing high benthic secondary production in estuaries. In: Ecology of marine benthos. Ed. by B. C. Coull. Univ. of South Carolina, Columbia, 267–280. (Belle W. Baruch Library in Marine Science. Nr 6.).