DEVELOPMENT OF PREDICTIVE MODELS LINKING FISH POPULATION RECRUITMENT WITH STREAMFLOW

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Observers watch things happen. Experimenters make things happen. Modellers predict the future!

In freshwater fisheries some environmental conditions, particularly streamflow, are amenable to large-scale management. This is a striking difference between freshwater fisheries and their marine counterpart, where there is little scope for environmental manipulation. Instead, the level of exploitation is currently the only major aspect of marine fish population dynamics that can be significantly influenced by management. In freshwater fish stocks, recruitment is not simply a random variable whose vagaries must be coped with; we can develop models whereby recruitment can be managed.

Recent debate on the sustainable management of freshwater resources has focussed new attention on the issue of streamflows. The alteration of natural streamflow patterns by river regulation has been linked to the decline of many freshwater and diadromous fish. In Australia, a particular problem is the effect on fish population recruitment caused by the suppression of flooding.

Flooding releases reproductive behaviour in several Australian species of fish after they have been conditioned by other environmental factors. Light and temperature, mediated through pituitary gonadotropins, are the commonest of these environmental conditioning factors regulating gametogenesis in seasonally spawning fish. Examples of species spawning in response to such conditioning and flood-release cues include golden perch *Macquaria ambigua* (Lake 1967) and Australian bass *M. novemaculeata* (Harris 1986). If the spawning season ends without the onset of suitable flooding, these fish can conserve the energy invested in ovarian yolk compounds by going through the process of ovarian involution and restoring abdominal fat depots. The adaptive value of spawning in floodwaters lies in the subsequent high survival rates of larvae; floods release accumulated nutrients from the catchment which trigger successions of plankton blooms, thus ensuring the availability of food for larvae.

Figure 1 is a conceptual model illustrating the recruitment process in both flood-cued and non-flood-cued species. Two broad phases of the model reflect the contributions of adult reproduction and larval survival to eventual recruitment. The model indicates that a number of specific stimuli may be required to induce spawning, and that flood-cued species may enter a holding loop until either a flood or involution occurs. Other fish species, such as Murray cod *Maccullochella peeli*, and possibly silver perch *Bidyanus bidyanus*, do not require flooding to spawn (Rowland 1983), but larval survival and strong cohorts are nevertheless favoured by suitable flooding, which frequently coincided with spawning seasons in the Murray-Darling basin under natural flow conditions before intensive river regulation (Thomson 1992).

The requirement to manage water resources for fisheries values led to a need for predictive models linking fish recruitment and streamflows. Two similar preliminary models have been developed, dealing with recruitment among Australian bass populations in coastal rivers, and golden perch in the inland. Both examples follow the conceptual model presented in Figure 1.

Australian bass

Age-frequency distributions of Australian bass in the Hawkesbury River system show marked instability in annual recruitment. To investigate the cause of this variation, estimates were made of the initial cohort strength, N_0, of 12 year-classes (Harris 1988), using the equation $N_0 = N_t e^{Zt}$, where N_t is observed abundance after t years and Z is the instantaneous rate of total mortality.

Relative initial year-class abundance was calculated as the contribution of each year-class to the total sample, expressed as a percentage. Plots of percent relative initial year-class abundance against time, with river flows in the Hawkesbury and Colo rivers during the spawning months of July and August in the year of spawning (Figure 2), showed significant positive correlations (as well as strongly declining annual recruitment). Winter-flood years produced strong cohorts, cohort abundance increased with the magnitude of flooding, and recruitment failed in drought years.

This relationship between bass cohort strength and winter streamflow is probably influenced to some degree by additional factors such as spawning-stock variation. Recruitment during the period 1990-1992 did not follow the model, and it is possible that a feed-back mechanism is also operating, in which an abundant bass population is somehow able to inhibit spawning in otherwise suitable conditions to avoid excessive population density. Nevertheless, the flood-recruitment model has provided a useful, but so far unvalidated, basis for practical streamflow management in the Hawkesbury and similar regulated coastal river systems.

Golden perch

Of the various inland species postulated, only golden perch have so far provided strong evidence of conforming to a flood-cued recruitment model, with equivocal evidence for silver perch (Lake 1967). This relationship has not yet been well quantified. But, as with bass, it is reasonable to expect that golden perch probably mirror the adaptations of other species having similar life-histories and distributions.

Like Murray cod and silver perch, golden perch recruitment, as indicated by subsequent commercial fisheries catches, is strongly favoured by flooding in their spring-summer spawning period. However, this evidence does not permit us to discriminate between the two roles of flooding, either

- controlling gonadal maturation and spawning behaviour, as in the adult phase of the flood-recruitment model, or
- enhancing survival and growth of cohorts of larvae and juveniles, as in the larval phase of the model, irrespective of the factors which induced spawning.

Flood-cued spawners therefore control their spawning activity to increase larval survival, whereas enhanced survival producing strong cohorts of other species depends more on the probability of spawning coinciding with high streamflows. This point might be of academic interest only, but for the differences among species in their fecundity and apparent spawning locations. Golden perch are migratory and highly fecund, and they seem to spawn in particular localities, rather than broadly throughout the adult habitat as in the case of Murray cod. The significance of this is that managing local streamflows to boost recruitment for a basin-wide migratory stock is a far more achievable task than providing comparable flood flows throughout large areas of the basin. Successful development of a predictive model for golden perch would permit a test of the value of manipulating recruitment using realistic water allocations.

References

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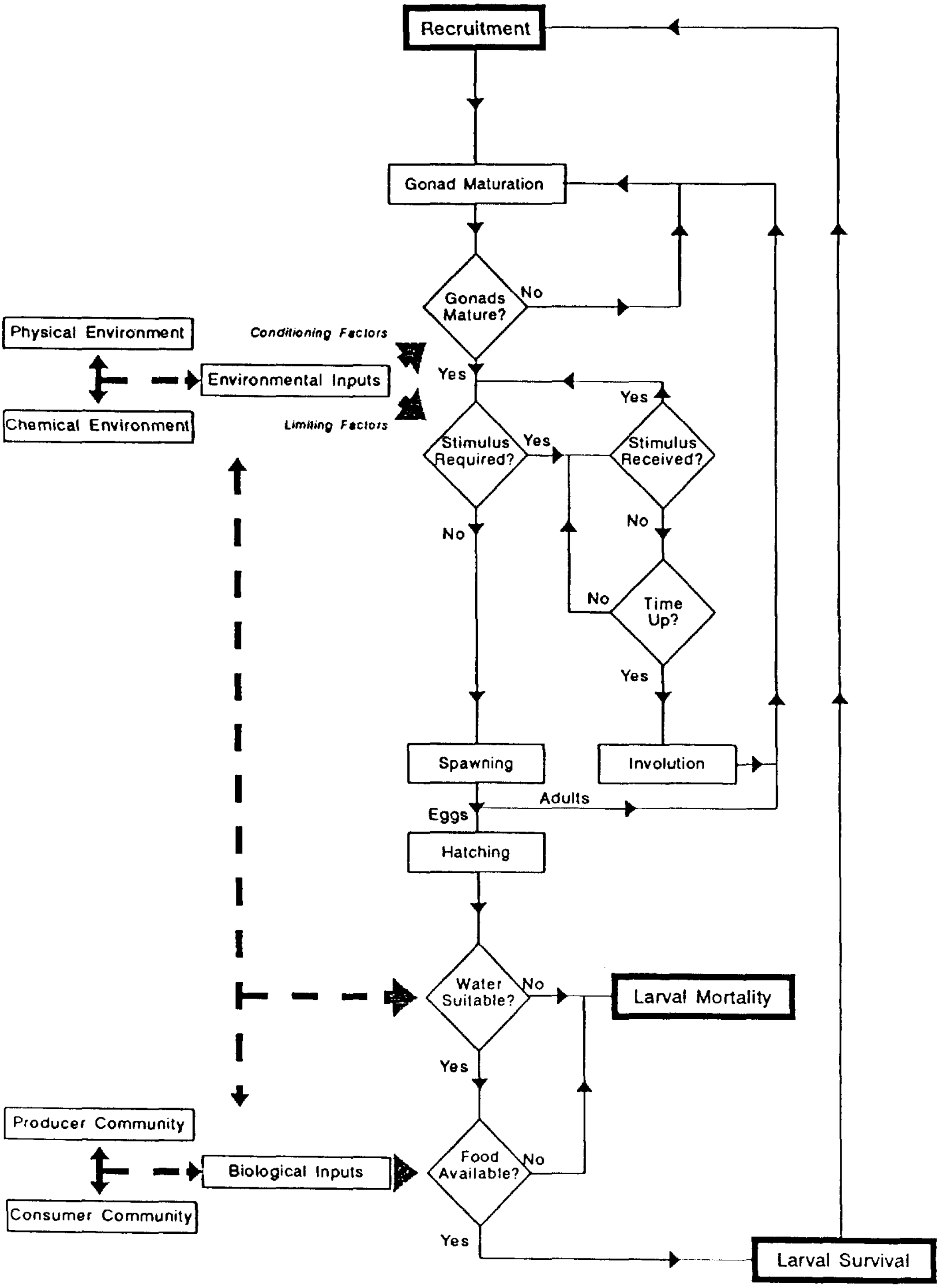

Figure 1. The flood-recruitment model for Australian native fish, with the adult (upper portion) and larval phases of the recruitment process.

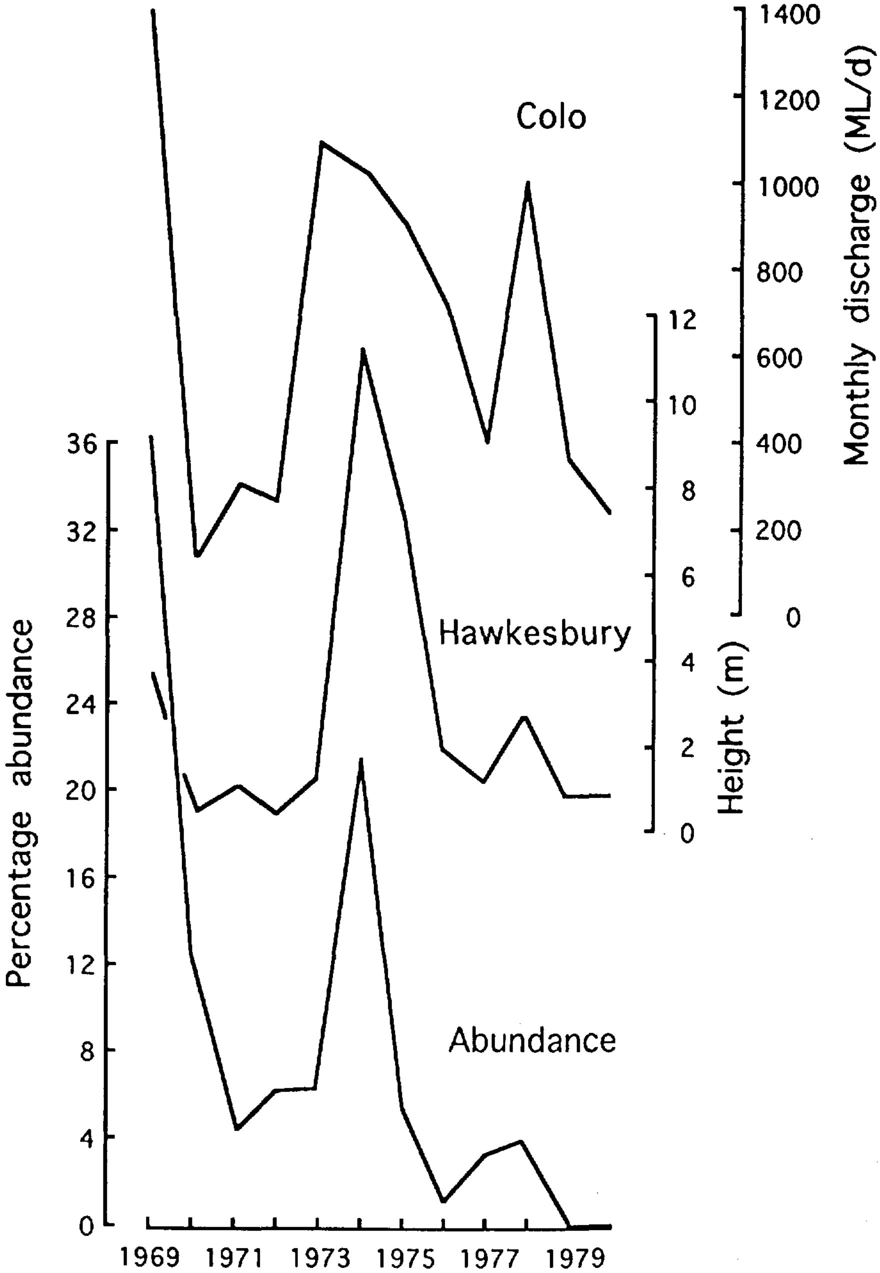

Figure 2. Relative initial year-class abundance of Australian bass in the Hawkesbury River system over a 12-year period. Percentage abundance is compared with average discharge of the Colo River, and peak height of the Hawkesbury River at North Richmond, during the spawning months (July and August) of the year of spawning of each year-class.