NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Developing fishery-independent surveys for the adaptive management of NSW's estuarine fisheries

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FRDC Project No. 2002/059

October 2008

NSW Department of Primary Industries –
Fisheries Final Report Series
No. 106
ISSN 1449-9967

NSW DEPARTMENT OF PRIMARY INDUSTRIES

Australian Government
Fisheries Research and Development Corporation

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October 2008

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Published By:	NSW Department of Primary Industries (now incorporating NSW Fisheries)
Postal Address:	Cronulla Fisheries Research Centre of Excellence, PO Box 21, NSW, 2230
Internet:	www.dpi.nsw.gov.au

ISSN 1449-9967

(Note: Prior to July 2004, this report series was published as the 'NSW Fisheries Final Report Series' with ISSN number 1440-3544)

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ACKNOWLEDGEMENTS

This project was a co-operative study between the Australian Fisheries Research and Development Corporation (FRDC), the Wild Fisheries Program of the NSW Department of Primary Industries, the Centre for Research on Ecological Impacts of Coastal Cities at The University of Sydney. We thank members of the Scientific Advisory Committee for their advice and support throughout the project. Thanks are also extended to Dr Matt Broadhurst for his invaluable contribution towards many aspects of the research. Alan Bodycote, John Brown, Gary Howard are thanked for providing technical assistance, advice and use of their vessels. We are also very grateful to the staff that assisted with fieldwork namely Paul Lokys, Lachlan Barnes, Damien Young, Ben Kendall and James McLeod. We also thank: Dr Steve Kennelly for his advice and support throughout the project; Dr Will Macbeth for assistance with selectivity analyses; Darren Reynolds for reviewing an earlier draft; and the numerous other staff at NSW DPI that provided assistance along the way.

NON-TECHNICAL SUMMARY

2002/059	Developing fishery-independent surveys for the adaptive management of NSW's estuarine fisheries

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OBJECTIVES:

1. Develop scientific sampling tools to catch the widest possible size range and diversity of fish species in NSW's estuaries.
2. Use the gears developed in objective 1 to do pilot studies to determine the most cost-effective, optimal number of replicates, sites, locations and habitats to be sampled in and among estuaries.
3. Use the results from objectives 1 and 2 to design the optimal sampling regime that will become the long-term, large-scale survey of the fish populations in NSW estuaries.

NON TECHNICAL SUMMARY:

Outcomes Achieved

Using an experimental strategy, this project successfully developed methods to use multi-mesh gill nets and a beam trawl as tools for sampling a wide size range and diversity of fish and crustaceans in estuaries of NSW. Experiments also measured spatial and temporal variation of estuarine fauna sampled with these gears and provided variances for cost-benefit analyses. Owing to the variable and dynamic nature of these fauna, however, the project has identified numerous challenges that require the development of novel analytical approaches (which are underway), before a large-scale and long-term survey can be designed and optimised across multiple species. Additional research is also needed to compare decision-making incorporating fishery-independent methodologies against that using data from fishery-dependent sources. This will identify the most reliable, robust and cost-effective sampling programmes required to improve the sustainability of NSW's estuarine fisheries resources.

Estuaries in NSW support a wide diversity of fish and invertebrates, which are subject to commercial and recreational fishing and a range of other human-induced pressures (e.g., habitat degradation, pollution). At present, monitoring of these aquatic resources relies entirely on data from fishery-dependent sources. This includes information provided by commercial fishers about how long they spend fishing and the quantities of each species that are retained. Other data, such as the size-distributions and ages of a few species, are obtained from commercial landings by researchers at ports and markets. Periodic surveys of recreational fishers and sampling of their catches are also done for a small number of estuaries in NSW.

The limitations of using fishery-dependent data for the assessment and management of fisheries resources, particularly in accordance with principles of ecologically-sustainable development (ESD), are well-known. For example, these data: (i) provide no information on species that are

discarded or not caught (e.g., undersize fish and species of no commercial value); (ii) often are not available in estuaries that are closed to fishing or where fishers' choose not to fish; and (iii) are biased and imprecise because of the selectivity of fishing gears, reporting errors and the varying practices and levels of skill across many different fishers. So, the future use of fishery-independent surveys has been advocated to provide a potentially improved quality of information on the status of estuarine fisheries resources in NSW.

Data collected independently of commercial and recreational fisheries using standardised, properly-designed research surveys, are generally less susceptible to the limitations of fishery-dependent data. Sampling gears and surveys are not, however, always properly designed and so can provide data that are also probably biased, imprecise, and costly. The preferred approach for developing reliable and cost-effective surveys is an experimental one, which uses pilot studies to test the design and deployment of sampling gears. This led to the present study, which was to do the necessary pilot work to develop scientific tools and designs of sampling for large-scale and long-term survey of fisheries resources in estuaries of NSW.

Based on key literature on surveys of fisheries resources and experimental design, we developed and used a general experimental strategy to meet the specific objectives of the project. Briefly, the strategy involved: (i) identifying suitable gear to sample target species; (ii) testing configurations of gear and sampling practices to ensure that samples are optimal, representative and cost-efficient; (iii) understanding spatial and temporal variability; and (iv) cost-benefit analyses to determine optimal levels of replication.

We followed the above strategy for two types of gears: multi-mesh gill nets and a beam trawl. These gears sampled a wide size range and diversity of fish and invertebrates (> 60 species), including many species of commercial and recreational importance (Objective 1). Experiments included a comparison of the utility and efficiency of multi-mesh gill and trammel nets. Gill nets were superior, so we tested the effects of using different lengths of net, soak and setting times. Experiments with the beam trawl tested the effects of factors such as the size of mesh in the body and codend, tow duration and diel period (day vs night). A key result of this work was that replicate gill nets and trawls required only short periods of deployment (compared to commercial practices), which had benefits for improving replication and potentially reducing the number of organisms that were harmed or killed.

After determining an optimal configuration and sampling protocol for each gear, we used the gill nets and beam trawl to measure spatial and temporal variation of estuarine fauna over a range of scales (e.g., zones, sites, days, weeks, months, seasons, etc). Such experiments identify appropriate scales of replication for future studies and allow numbers of replicates to be optimised using standard cost-benefit analyses (Objective 2). In our study, individual species and assemblages were extremely patchy at the smallest spatial scale examined (i.e., among replicates) – a pattern that was consistent across gears, depths and estuaries. There were, however, no consistent patterns of variation among the different temporal scales (e.g., days, weeks, months, seasons) for either method of sampling. The only consistent pattern across different species and gears was that variation among replicates (i.e., small-scale spatial variation) was greater than variation at any temporal scale.

The patchiness of many species among samples often precluded sensible univariate cost-benefit analyses. Although cost-benefit analysis was also done on assemblages of species, it may not be appropriate because it was uncertain how different taxa contribute to an optimal design, or whether it was suitable for all species in an assemblage. Further, current analytical procedures cannot determine (or optimise) the power of sampling for assemblages of species. So, before a large-scale and long-term survey can be designed (Objective 3) new analytical techniques are needed to attempt to develop cost-benefit analyses for multiple species. These new procedures are currently being developed because, prior to this project, there were no data available to address these problems for assemblages of fish in NSW. Further research is needed to test how to use fishery-independent data in making managerial decisions, the cost and benefits of using such data and whether better outcomes are achieved. This will identify the most appropriate sampling programmes for improving the management of fisheries resources and biodiversity in estuaries of NSW.

KEYWORDS: fishery-independent surveys, estuaries, fish, multi-mesh gill net, beam trawl, cost-benefit analysis, New South Wales

1. BACKGROUND

The management of most commercial and recreational fisheries in NSW estuaries is currently undergoing significant change through a variety of initiatives including the creation of several Recreational Fishing Havens, Marine Parks and Reserves, the buy-out of some commercial fishing effort and the development of Environmental Assessments and Fisheries Management Strategies. In addition to these initiatives, the population density of NSW continues to increase and there have never been greater pressures on our estuaries from pollution, land management practices, etc. Throughout all this change, there is a continuing need to maintain our aquatic resources for current and future generations of commercial and recreational fishers as well as to assess the success of those management initiatives that are designed to ensure the sustainability of those resources.

At present, the assessment of NSW’s estuarine commercial and recreational fish stocks relies heavily on fishery-dependent information, primarily the catch and effort information supplied by the commercial sector, augmented with some biological sampling of commercial landings for a few key species. These data have minimal utility for fisheries management because: (i) no information is obtained where no fishing takes place (whether that is due to legislative closures and/or fishers’ individual choices); (ii) no information is obtained on the critical undersize portion of the exploited populations (which includes the next generation of targeted fish); (iii) no information is obtained on other species that are considered not worthy of retention in any place/time (for whatever reason); (iv) such information is often inaccurately or imprecisely recorded; and (v) the data obtained has little scientific rigour because commercial and recreational fishing is mostly done in biased, non-independent ways – i.e., the execution of any “replicate” fishing attempt DEPENDS on the results of previous attempts.

Clearly, we need a better way to collect information on our estuarine fisheries resources if we are to manage them sustainably. We also need a better way to assess the success (or failure) of management initiatives that are designed to improve them in adaptive management frameworks (i.e., frameworks that are sufficiently responsive and flexible to respond appropriately to quality scientific information). To do this, we must have data on the relative abundances of fish in estuaries and demographic information (i.e., length, sex, and age composition, reproduction and recruitment dynamics) on the various life-history phases of these populations, including those stages prior to capture. We also need this information in places and times where fishing does and doesn’t always occur (i.e., inside closed areas as well as open areas, in places/times where fishers choose not to fish as well as places/times where they do, etc.). This type of data can only be gathered via standardized, fishery-independent surveys.

2. NEED

The above Background explains why it is necessary to develop a standardized fishery-independent sampling strategy to provide estimates of relative abundances and demographies of populations of fish in the estuaries of NSW which will be used in conjunction with existing and any new sources of fishery-dependent data (from commercial and recreational fisheries). Before these surveys can be implemented, however, it is necessary to do several pieces of very important research.

First, the correct sampling tools and methods need to be developed. Whilst we acknowledge that commercial and scientific fishing gears are available, these have been designed to capture very specific species and sizes of species. We need to modify these and other gears to develop new techniques that will sample wider size ranges and diversities of fish than is the case for commercial and recreational fisheries. Specifically, we need to determine the best suite of gears to use to catch as wide a size and species range of fishes as possible in as many different habitats as possible.

Second, once the best tools have been developed, appropriate spatial and temporal scales of sampling and units of replication need to be determined so that an ongoing survey design based on a rigorous sampling protocol can be implemented for the decades to come.

3. OBJECTIVES

1. Develop scientific sampling tools to catch the widest possible size range and diversity of fish species in NSW's estuaries.
2. Use the gears developed in objective 1 to do pilot studies to determine the most cost-effective, optimal number of replicates, sites, locations and habitats to be sampled in and among estuaries.
3. Use the results from objectives 1 and 2 to design the optimal sampling regime that will become the long-term, large-scale survey of the fish populations in NSW estuaries.

4. METHODS

4.1. Study area

Experiments were done in a number of different estuaries in NSW, spanning a distance of almost 700 km along the coast (Fig. 1). More specific details (or links to key references) of each estuary are provided in the relevant manuscripts and summaries in the appendices.

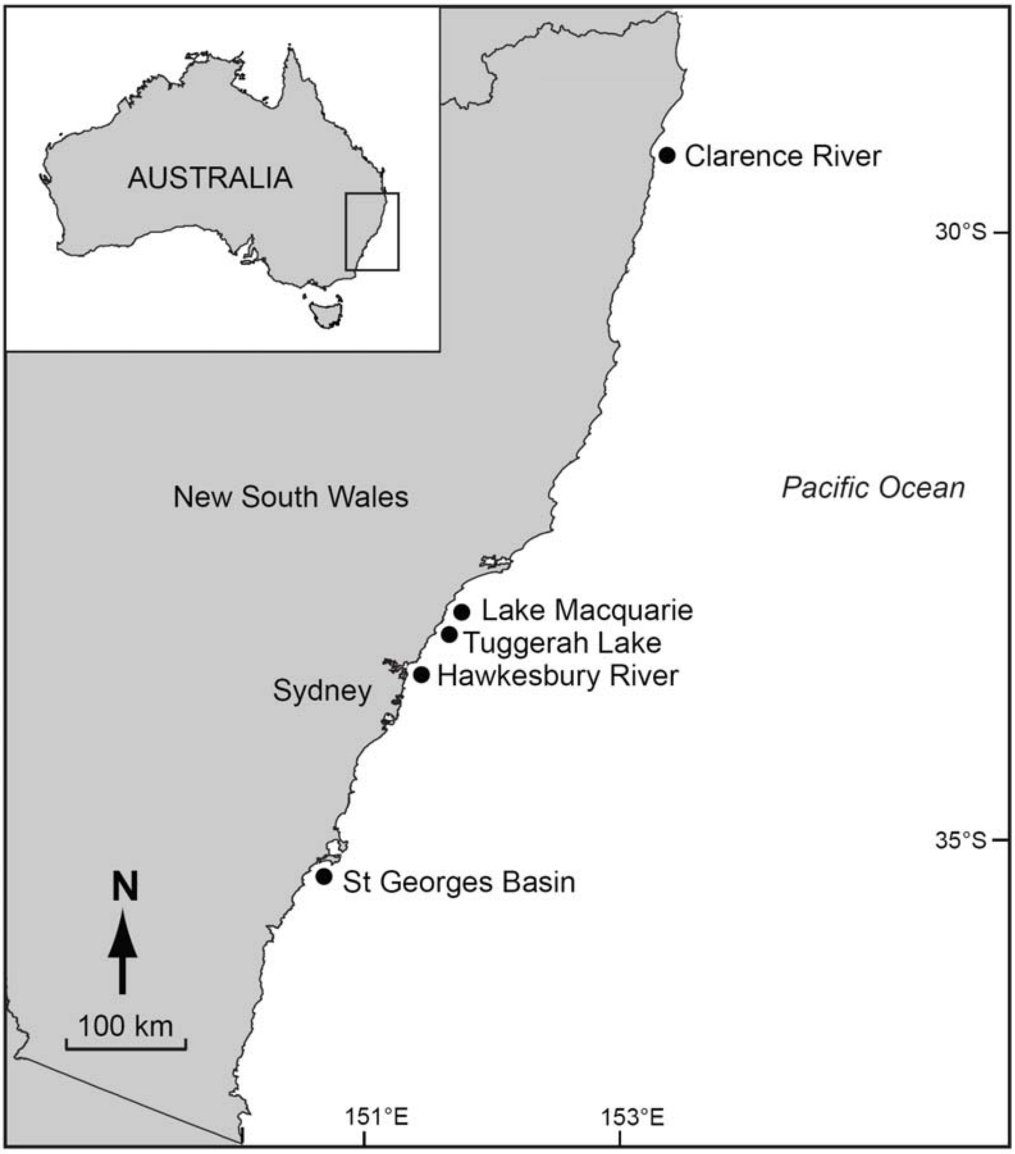

Figure 1. Map of the NSW coast showing the locations of the estuaries where experiments were done.

4.2. An experimental strategy

This project is underpinned by an experimental approach that involves testing of hypotheses. The importance of doing pilot experiments to develop more reliable and cost-effective sampling tools and designs of sampling is generally well-known (Andrew and Mapstone, 1987; Underwood, 1997). Many experimental studies have: (i) compared methods of sampling fish or invertebrates (e.g., Guest et al., 2003; Olin and Malinen, 2003); (ii) tested the effects of biotic and abiotic factors on the performance of sampling gear (e.g., Acosta, 1994; Misund et al., 1999; Petrakis et al., 2001); or (iii) measured spatial and temporal variation in numbers of organisms across hierarchical scales (e.g., Morrisey et al., 1992a, b). There are, however, few examples of necessary pilot work being done before commencing large scale and long term fishery-independent surveys (e.g., Kennelly, 1989; Kennelly et al., 1993). Often, surveys are done using commercial fishing gears and inappropriate designs of sampling, which may provide data that are biased, inaccurate, imprecise and costly. Thus, the hypothesis that fishery-independent sampling provides more reliable and robust information than data from fishery-dependent sources, remains largely untested.

We reviewed: (i) previous fishery-independent studies that have used pilot experiments to develop and optimise methods and designs; and (ii) key literature on surveys of fisheries resources (e.g., Gunderson, 1993) and design and analyses of ecological experiments (e.g., Andrew and Mapstone, 1987; Underwood, 1997). Many surveys did not use a consistent approach to designing sampling gears or surveys. Therefore, we brought the elements together into a general strategy for this type of preliminary work, following an experimental approach advocated in previous studies in NSW (e.g., Kennelly, 1989; Kennelly et al., 1993). The strategy involves: (i) identifying suitable gear to sample target species; (ii) testing configurations of gear and sampling practices to ensure that samples are optimal, representative and cost-efficient; (iii) understanding spatial and temporal variability; and (iv) cost-benefit analyses to determine optimal levels of replication (Fig. 2). More specific details of the strategy are in Rotherham et al. 2007 (Appendix 4). The logical sequence of the strategy addresses the objectives of this project.

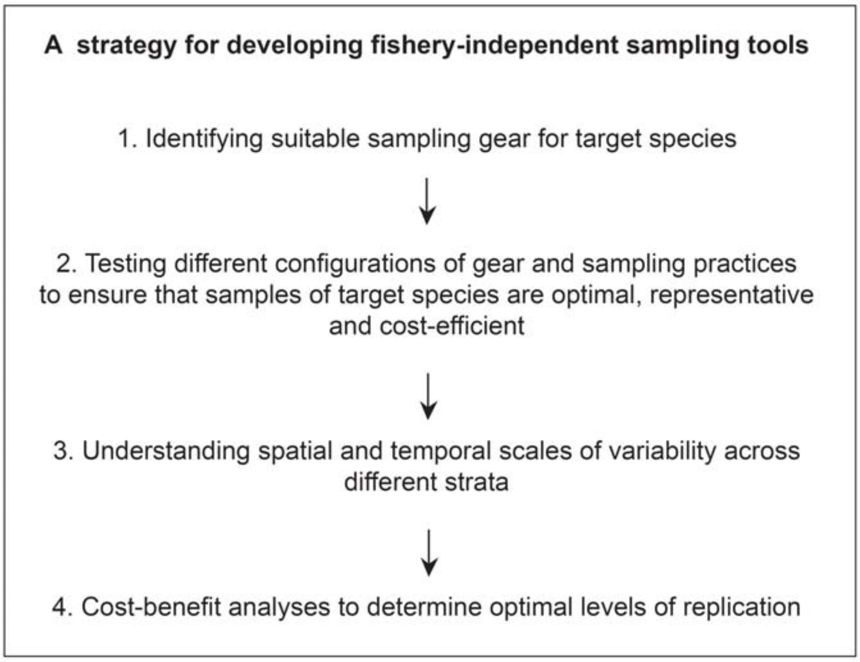

Figure 2. Steps in the strategy used to develop fishery-independent sampling tools.

4.3. Sampling gears

Many methods are used by commercial fishers in estuaries of NSW; the most common are meshing (gill nets), hauling (seining) and trawling (Anon, 2003a, b). These methods catch a diverse range of fish and invertebrates. Nevertheless, using commercial configurations and fishing practices is often inappropriate for scientific sampling (see above). So, we followed the above strategy for two different types of gears: (i) multi-mesh nets; and (ii) trawls.

4.3.1. Multi-mesh nets

In general, multi-mesh nets are either gill nets (single wall of netting) or trammel nets (two large-meshed walls of netting enclosing a loosely-hung centre wall of netting) comprising panels of more than two sizes of mesh (Fig. 3). These sorts of gears are designed to catch a wider range of sizes (and species) of fish than commercial meshing gears (which typically use a single size of mesh). Multi-mesh nets (particularly gill nets) have been used throughout the world for sampling fish and invertebrates (Loneragan et al., 1987; Degerman et al., 1988; Mattson and Mutale, 1992; Acosta, 1997), mainly because they are relatively inexpensive and are easy to deploy and retrieve. Another benefit is that they have minimal impacts on the habitat that is sampled.

Multi-mesh nets are often deployed in gangs with continuous (i.e., no gaps between adjacent panels) or discrete (gaps between adjacent panels) connections. We used discrete connections in all of our nets (Fig. 3) to: (i) reduce non-independence between adjacent nets; and (ii) minimise the potential of small-meshed panels leading fish into larger-mesh panels (Hamley, 1975; Pope et al. 1975).

We used between 3 and 5 sizes of mesh for experiments with multi-mesh nets in Steps 1 and 2 of the strategy (Appendix 6 and 7). We considered this to be sufficient to provide some generality of results for the hypotheses tested. Further, using additional sizes of mesh in these experiments would have restricted levels of replication by imposing logistic constraints. All of our experiments in Step 3 of the strategy, however, used seven sizes of mesh (36, 44, 54, 63, 76, 89, 102 mm, stretched mesh), in a random order, with gaps of 5 m between each panel. The difference between successive sizes of mesh was approximately geometric (i.e., successive sizes of mesh differed from one another by an almost constant ratio). Using a geometric progression of mesh sizes, as opposed to an arithmetic progression (i.e., where each mesh differs from the succeeding mesh by a constant amount), is required so that each size of mesh fishes with similar efficiency (see Regier and Robson, 1966; Pope et al., 1975; Jensen, 1986). We considered this important for testing hypotheses about differences in patterns of abundance over different spatial and temporal scales.

4.3.2. Trawls

Trawls are funnel-shaped nets (Fig. 4) that are towed through the water behind a boat. There are many different types of trawls (von Brandt, 1984). Otter trawls and beam trawls are commonly used in bottom-trawl fisheries and have been widely used as sampling gears in coastal environments worldwide (Stokesbury et al., 1999; West, 2002; Petrakis et al., 2001). We were interested in developing a trawling gear for sampling prawns, crabs and juveniles of key, economically-important species of finfish. Our trawl nets (both the beam trawl and otter trawl) were based on a 'Florida flyer' design (Fig. 4). This is widely used in prawn-trawl fisheries in eastern Australia (Hughes, 1972) and is known to retain key species of fish and invertebrates (Liggins and Kennelly, 1996). Other trawl-net designs are used elsewhere (von Brandt, 1984), but we did not test them against the Florida flyer design. Our experiments in steps 1 and 2 of the Strategy involved either manipulating the vertical opening of the nets, the sizes of mesh used in the body and coded, or the time of day or length of time the trawl was towed.

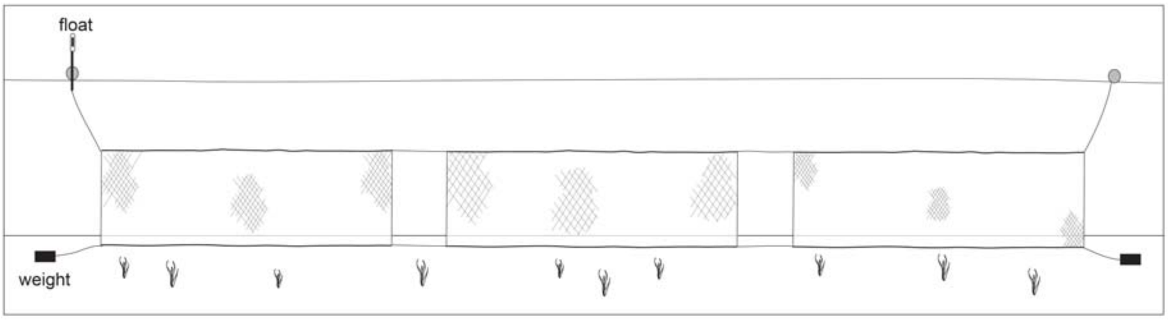

Figure 3. An example of a continuous multi-mesh gill net with discrete connections between adjacent panels of different sizes of mesh.

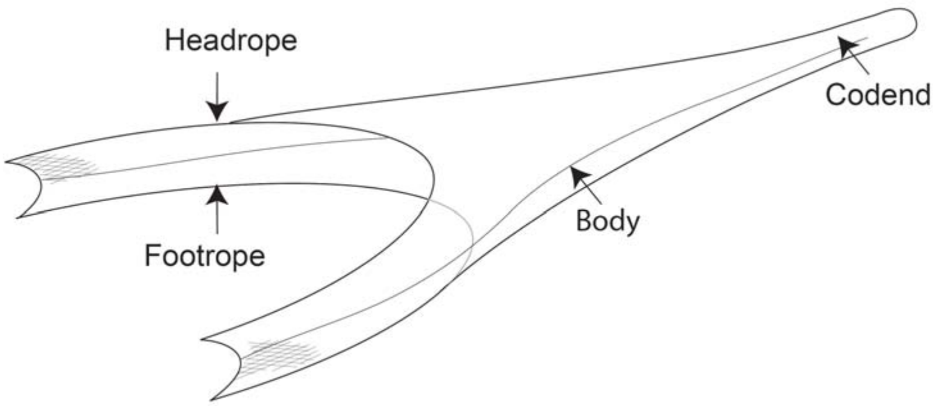

Figure 4. Design of a generic 'Florida flyer" trawl net used in NSW.

4.3.3. *Other gears*

We intended to follow the above strategy for a third type of gear (i.e., a beach-seine net). Sampling with haul nets is, however, considerably more time-consuming and labour-intensive than with gill nets or trawls, limiting the numbers of replicates that can be sampled in any given period. Our pilot work with gill nets and trawls revealed that among-replicate variability was large (requiring greater replication at this scale). Therefore, we decided not to develop a hauling net because, ultimately, this method would require additional staff (and therefore greater costs) and provide levels of replication that were likely to be inadequate. The Advisory Committee and project investigators also agreed that, before investing in additional sampling gears, it should first be demonstrated that the gears already examined in this project (i.e., the multi-mesh gill nets and beam trawl, see below) actually provide more reliable and cost-effective information than from fishery-dependent sources (see Chapter 8).

In recent times, there has been an increasing use and promotion of non-destructive sampling gears, such as baited remote underwater video stations (BRUVS, e.g., Willis and Babcock, 2000). We also considered using these sorts of gears. Nevertheless, BRUVS (and other visual techniques such as diver surveys) are not commonly used in estuaries owing to the turbidity of water, causing poor visibility. Many taxa in estuaries also follow diel patterns and are more abundant at night, which precludes the use of some visual methods.

A previous study in NSW showed that even in the lower reaches of an estuary, where visibility was relatively clear, BRUVS were only effective for sampling two species of fish (Ianna, 2004). In fact, studies of non-destructive methods, such as BRUVS, often conclude that it is necessary also to sample in concert with other gears (e.g., trawls, Cappo et al., 2004). Until there are significant advances in the technology of non-destructive methods (e.g., Didson SONAR), gears based on commercial fishing methods (as developed here) will continue to play an important role in sampling multi-species assemblages of fish and invertebrates in turbid, estuarine waters. Optimising gears and designs of sampling using the strategy outlined above can, however, reduce the numbers of organisms that are harmed or killed.

4.4. Summary of experiments

The experiments are summarised in Table 1. An initial experiment was done to identify a suitable multi-mesh gear (i.e., gill nets vs. trammel nets). For the trawling method, however, we simply identified otter trawls as being a suitable gear and proceeded to Step 2 of the strategy. After completing some initial experiments on the configuration of the otter trawl, we realised that sampling with this gear was difficult in shallow water. Further, either a commercial-sized vessel would be required to tow the gear in future, or we would have to scale down the gear. The scientific literature also discussed many problems of sampling with otter trawls: (i) catches of fish are often enhanced by the herding effects of the otter boards and rigging; and (ii) the horizontal opening of trawls can be highly variable (Gunderson and Ellis, 1986; Wardle, 1986). So, we decided not to proceed to Steps 3 and 4 of the strategy with the otter trawl. Instead, we decided that a large beam trawl would be a more suitable sampling gear (Step 1) because it overcame the problems of sampling with the otter trawl. We then completed the remaining steps in the strategy for the beam trawl.

In most cases, manuscripts relating to each experiment have been published, or submitted to, peer-reviewed scientific journals. Thus, the specific details of each experiment (i.e., the justification, materials and methods, analyses and results) are provided in these manuscripts, which are attached as appendices. For a small number of experiments, data have been analysed and interpreted, but manuscripts are still in preparation. In these cases, a summary of each experiment (the hypotheses tested, what was done and the main findings) is also attached as an appendix. The remaining chapters of this report provide a brief summary of the main results of each experiment (Chapter 5), a general discussion (Chapter 6) and implications of the research (Chapters 7, 8, 9, 10).

Table 1. Summary and location of experiments done for each type of gear during the project. TL = Tuggerah Lake; SGB = St Georges Basin; LM = Lake Macquarie; CR = Clarence River; HR = Hawkesbury River. Details of each experiment are found in the relevant appendix.

Experiments	Location	Appendix
Multi-mesh nets		
1. Comparison of multi-mesh gill nets and trammel nets	TL	6
2. Multi-mesh gill nets: effects of soak and setting time and panel length	TL	7
3. Multi-mesh gill nets: spatial variation of fish fauna	SGB, LM	8
4. Multi-mesh gill nets: temporal variation of fish fauna	SGB	9
Trawls		
5. Otter trawl: effects of net height and diel period and tow duration	CR, HR	5
6. Beam trawl: effects of a codend cover and mesh size in the body and codend	CR	10
7. Beam trawl: effects of diel period and tow duration	TL	11
8. Beam trawl: spatial and temporal variation of fish fauna	TL , LM	12