Effectiveness of larger mesh size in reducing the capture of juvenile target species in select NSW beach seine operations

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Did you know?

'It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change.'

SOURCE: Charles Darwin 1809 – 1882

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OBJECTIVES:

1. To examine and quantify the effectiveness of a larger than prescribed mesh size in reducing the capture of juveniles in ocean beach seine operations targeting ground fish species.
2. The provision of information to support management decisions for the long-term benefit of the resource and its users.

NON-TECHNICAL SUMMARY:

OUTCOMES ACHIEVED TO DATE

Trials to test the effectiveness of a larger mesh size in the beach seine nets used in the NSW Ocean Hauling Fishery were instigated by a commercial beach seining crew operating from Trial Bay, South West Rocks, located on the mid-north coast of NSW. The fishing crew had a genuine concern regarding the incidental capture of significant proportions of juveniles, whilst targeting migratory schools of ground fish when using currently legislated beach seine nets. The primary target species and also juvenile species of concern (i.e. bycatch) were Yellowfin Bream (*Acanthopagrus australis*), Luderick (*Girella tricuspidata)* and Tarwhine (*Rhabdosargus sarba*). These species are often collectively referred to as 'ground fish' in the NSW Ocean Hauling Fishery.

The effectiveness of using a larger mesh size was validated with promising results in all trials with adequate data. The project clearly demonstrated that increasing the mesh size throughout the posterior wings and bunt/codend to 102 mm can reduce the capture and subsequent mortality of juvenile ground fish species targeted during March to July. However, it is important to acknowledge that the mesh size trialled may only be suitable during certain times of the year, or at particular locations, and when targeting specific species.

The recommendations made in this report have been reflected in amendments made to the legislation governing the Ocean Hauling Fishery. On 1 April 2010 the regulated maximum mesh size in the seine net for ocean waters within 3 nautical miles of the natural coastline was increased from a maximum of 65 mm to a maximum of 102 mm in the bunt/codend for the taking of fish other than Sea Mullet.

A significant reduction in the capture and subsequent mortality of juveniles may be beneficial to the species biomass and to the sustainability of the fishery as a whole. In a practical sense, these changes could improve the efficiency of fish handling

practices, specifically reducing the time taken to sort catches. This may allow any remaining juveniles to be returned to the water faster, thereby improving survivability.

An important additional outcome is that commercial ocean beach seine fishers are empowered with installed confidence in their gear, and have the ability to reduce the potential conflict between the user groups of this common resource (commercial and recreational fishers and the broader community). The beaches on which these fishers operate, with a large majority of net deployments being carried out during daylight hours and at times within view of the general public, are popular holiday and fishing destinations. These species are also targeted by recreational fishers; therefore optimal survival of juveniles is paramount to both commercial and recreational fishers. The reduction in the incidental capture and mortality of juveniles will help to alleviate some of the conflict experienced between the resource users.

A trial to test the effectiveness of a larger-than-prescribed mesh size in reducing the capture of juvenile target species in the NSW Ocean Hauling Fishery was completed during April and May 2008 at South West Rocks**.** The legislation at the time enforced in this fishery between the period of 1 March and 31 July, prescribed a maximum mesh size of 86 mm in the anterior wings, 65 mm in the posterior wings, and 65 mm in the bunt/codend. This trial examined the effectiveness of releasing juvenile target species - Yellowfin Bream, Luderick and Tarwhine - from the prescribed gear configuration compared with a net of equal length and depth, but constructed of 102 mm mesh.

Promising results were obtained regarding the exclusion of undersized target species (i.e. bycatch) when using the modified configuration, with significant reductions found in the posterior wings and bunt/codend sections of the configuration. It is evident, that increasing mesh size can significantly reduce the incidental capture and mortality of juvenile target species. The proportion of less than minimum legal total length (MLTL) of Yellowfin Bream, Tarwhine and Luderick caught throughout the entire configuration was reduced by 64 %, 66 % and 47 %, respectively, using the modified configuration. It is expected, however, that such substantial reductions would be unlikely in all commercial operations due to the size composition of the schools targeted during these trials.

These results confirm the effectiveness of modifying the maximum mesh size regulations to a maximum of 102 mm throughout the net. These changes will most likely result in a decrease in the capture and mortality of juvenile ground fish species that are targeted from March to July in the NSW Ocean Hauling Fishery.

Participating fishers from the Ocean Hauling Fishery did not require written reports to decide on the effectiveness of increasing the mesh size during certain times of the year. The positives were clearly evident as the catches were landed. The fishers had been pleading for a number of years for legislation to be modified but they needed the scientific proof that their idea of increasing the mesh size held merit. Reports outlining the results of the trails were distributed to the Ocean Hauling Fishery Management Advisory Committee and to I&I NSW for consideration, comment and extension to the beach seine fishers.

KEYWORDS: Ocean beach seine, mesh size, Yellowfin Bream (*Acanthopagrus australis*), Luderick (*Girella tricuspidata),* Tarwhine (*Rhabdosargus sarba*).

Acknowledgments

This work was funded by the Fisheries Research and Development Corporation (FRDC) on behalf of the Australian Government and would not have been possible without their financial support. Much appreciation is extended to OceanWatch Australia for their administrative role and providing employees of the SeaNet Program to conduct research gratis, drastically reducing costs. I&I NSW must be thanked for their management support. Also thank you to David Makin and Darren Reynolds for assistance acquiring the necessary permits, and to Dr Matt Broadhurst for his assistance and advice on a suitable methodologies. Reviewing of the report by Peter Ward and Emma Bradshaw was greatly appreciated.

Special thanks must also go to the commercial fishers of South West Rocks who not only instigated the project, but tolerated researchers occupying their space and complicating their fishing operations. The project truly benefited from their experience, insight and hospitality. Participating fishers were Bob and Gary Baker, Dave Mitchell, Marg Park, Brad Holden, Geoff Blackburn, and Vince and Zac Jordan. Thanks also extended to Kate Milner, Tam Holden and Leonard Southwell for their assistance.

Background

The NSW Beach Hauling Fishery

The NSW Beach Hauling Fishery targets approximately 20 benthic and pelagic fish species. One component of the fishery, seines deployed from oceanic beaches, harvest almost 4000 tonnes of seafood annually and around 90% of catches (by weight) consist of Luderick, Silver Biddy (*Gerres subfasciatus*), Trumpeter Whiting (*Sillago maculata*), Sand Whiting (*Sillago ciliata*), Yellowfin Bream, Eastern Australian Salmon (*Arripis trutta*) and Sea Mullet (*Mugil cephalus*). This product is sold to domestic and international markets and valued at approximately AU$9 million annually.

The NSW Beach Hauling Fishery is a limited entry fishery managed by input controls, including limitations on the size and dimensions of nets used. Minimum legal total lengths apply to the majority of species targeted in the fishery.

(Source: http://www.dpi.nsw.gov.au/fisheries/commercial/fisheries/ocean-hauling)

Bycatch Reduction

For many years, the issue of bycatch reduction has dominated fisheries research around the world. In recent times, there have been many advances in bycatch mitigation, resulting in significant benefits to fisheries and fishery resources. Considerable research in this field has been conducted in Australia, but at present there is very little data available on the beach seines deployed from NSW oceanic beaches. No publications quantitatively describe the catch composition of the NSW Beach Hauling Fishery, the spatial and temporal variations in catches (both target and non-target species) nor the percentage of juvenile fish which are subsequently discarded (i.e. bycatch).

Previous Research

Broadhurst *et al*. (2006) demonstrated that the mesh sizes legislated in NSW beach seines were inappropriate in maximizing size selection for most of the targeted species. A recommendation was that the morphology of the species of concern should be considered when determining the appropriate mesh size. Target species morphological studies (for example, maximum girth versus available mesh opening) were utilized to determine an appropriate mesh size of between 90 mm and 101 mm.

The selection mechanisms of NSW estuarine deployed beach seines were further investigated in Broadhurst *et al.* (2007). These trials examined the effect of different sized mesh in the posterior wings (57 mm to 80 mm) and bunt (33 mm to 63 mm to 80 mm) on catches. They concluded that increasing mesh size may be an effective strategy to reduce bycatch.

More recently, Wooden (2007) investigated the use of an alternate net configuration, specifically increasing mesh size in the bunt/codend to 102 mm in ocean deployed beach seines, exploring the relationship between morphological features and the current legislated mesh sizes. Conclusions were:

(i) That current configurations of NSW beach seines are inappropriate for maximizing size selectivity for many targeted species;

(ii) It is necessary to consider morphological data to predict and trial appropriate mesh sizes to reduce bycatch; and

(iii) That no significant physical or physiological damages resulted from juvenile bream escaping from a modified beach seine with a larger mesh size (102 mm), in simulated laboratory experiments.

Current Research

This research is expanding on various components of Wooden (2007) in which field experiments evaluated the effectiveness of a net constructed with conventional mesh size in the anterior and posterior wings, and a modified bunt/codend constructed from 102 mm mesh. NSW beach seine fishers use gear similar to the generic beach seine illustrated in Figure 1. It is important to recognise the 'bunt' commonly refers to the middle third of the seines total headline length (m), as per fisheries legislation.

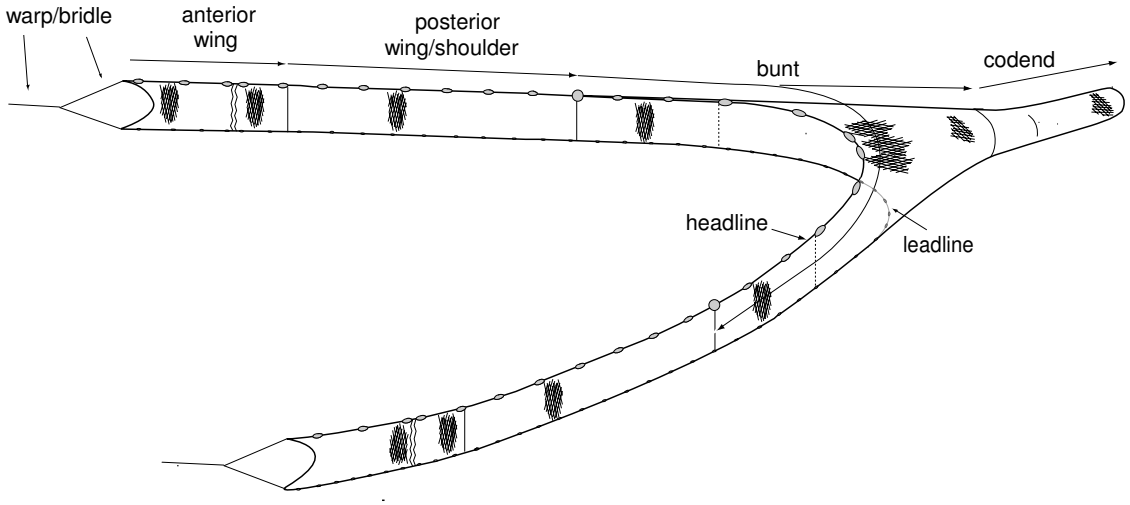

Figure 1 Diagrammatic illustration of a generic beach seine and the various components.

There have been genuine concerns from industry members regarding the potential capture of significant proportions of juveniles, whilst targeting migratory schools of ground fish (generally during non-spawning migrations) when using currently legislated beach seine net specifications. The legislation at the time, enforced in this fishery between the period of 1 March and 31 July, prescribed a maximum mesh size of 86 mm in the anterior wings, 65 mm in the posterior wings or shoulders, and 65 mm in the bunt/codend (Figure 1). Whilst these dimensions are believed to be appropriate for Sea Mullet (*Mugil cephalus*), they prevent the escape of juvenile ground fish due to differences in morphology.

Limitations

Prior to commencing this research, heavy rains affected the mid-north coast causing several major river and lakes systems to the south of South West Rocks to reach minor flood levels (Hastings River, Manning River and Wallis Lake). The timing and intensity of the rain led to large influxes of fresh water into these systems, effectively driving large amounts of fish to prematurely leave estuaries and migrate north along the coast. These schools of fish were comprised of mixed species and are characterised by a wide variety of size classes. While this situation provided a great medium on which to test the effectiveness of nets comprised of a larger mesh size, it is not a true representation of industry practice, as many of these schools of fish would not always be targeted or netted. Additionally, poor visibility may impede

beach haul fisher's ability to visually observe mitigations. The seasonal migratory run of reproductively mature ground fish that are routinely targeted, in contrast, generally consists entirely of large individuals of the same species

Some beach seine crews assess the size class and species structure of the travelling migration to determine what gear to deploy, or in some instances, not to deploy. The efficiency of which is influenced by the crew's experience in visual identification and knowledge of school shape, colour, depth and migration behaviour.

Need

Concerns regarding bycatch in the NSW Ocean Hauling Fishery involve the discard and potential mortality of juvenile species unintentionally caught whilst targeting mature individuals of recreational and commercial importance. Anecdotal information from numerous sources, including researchers, the general public, commercial and recreational fishers, industry representatives and the Ocean Hauling Management Advisory Committee (OHMAC), has identified the need for research on the landings of juveniles in conventional beach seine gears.

The Fisheries Management Strategy for the Ocean Hauling Fishery (2003) describes in Chapter 8 (Goals, Objectives and Management Responses) the vision of the fishery. Namely, *a profitable Ocean Hauling Fishery which provides the community with fresh local seafood, high value exports, and carries out fishing in an ecological sustainable manner.* This research clearly relates to the vision of the fishery and directly addresses many objectives listed under the fishery goals.

Additionally, this research focuses on the specific outcome of a reduction in bycatch of juvenile target species encountered in the ocean beach seine operations for the long-term benefit of the resource. This outcome addresses the FRDC high priority for research by responding to strategic challenge 1: to maintain and improve the management and use of aquatic natural resources to ensure their sustainability.

On various occasions there has been tension between the resource user groups, commercial beach seine fishers, recreational fishers, and the broader community. Beach seine operations are often observed by members of the public and the mortality of juveniles of targeted species is of significant concern. The findings of this study may help in alleviating the potential for conflict.

This project is an industry initiative aimed at reducing resource wastage by lowering the amount of incidental bycatch of juvenile target species encountered in ocean deployed beach seines. The sustainability of the fish stocks impacted by the fishery will improve, as well the long-term sustainability of the NSW Ocean Hauling Fishery.

Objectives

1. To examine and quantify the effectiveness of a larger than prescribed mesh size in reducing the capture of juveniles in ocean beach seine operations targeting ground fish species.

2. The provision of information to support management decisions for the long-term benefit of the resource and its users.

Methods

The aim of this project was to compare the effectiveness of the prescribed configuration with a net of comparable length and depth, constructed entirely of 102 mm mesh, in releasing juvenile target species (i.e. bycatch) when encountered. There were two stages of the study - Part 1 and Part 2. The various components and their lengths (m) of a generic beach seine are in Figure 2.

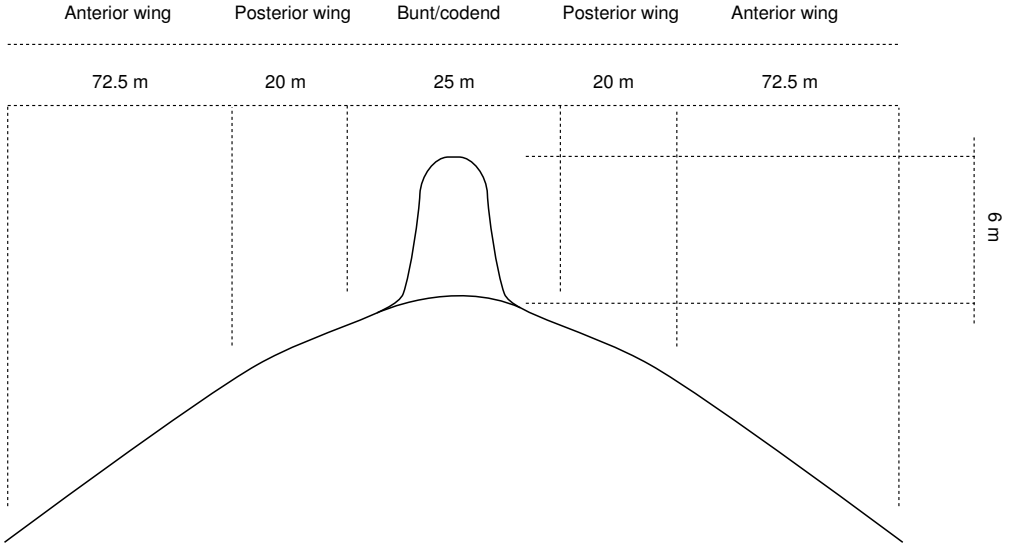

Figure 2 Top view of a generic beach seine and the various components

Methodology of Part 1

The trial gear comprised a net constructed entirely from 102 mm meshing, with comparable length and depth dimensions to the currently legislated net used by the South West Rocks hauling crew (i.e. a maximum mesh size of 86 mm in the anterior wings, 65 mm in the posterior wings and 65 mm in the bunt/codend). For the purpose of this study, the net that met the current legislative requirements was termed the 'conventional' net and the net of the same dimensions constructed from the larger mesh was termed the 'modified' net.

The mesh size of the modified net was chosen due a recommendation from Broadhurst *et al.* (2006). Morphological studies on Yellowfin Bream determined the appropriate mesh size would be between 80 and 101 mm. However, the closest commercially available mesh size was 102 mm.

Ocean deployed beach seines were completed on travelling schools of ground fish using an alternate haul methodology (see King, 2007) with the conventional and modified beach seine configurations. Following observation of the first school of the day, a coin toss determined if the modified or conventional gear would be deployed to target the school. When a second school was observed on the same day the other gear type was deployed. This was repeated throughout the day and restarted the following day using another coin toss to determine the first gear type used. Timing of completed shots (boat deployed from beach to boat landed and hauling commenced) between the two nets was comparable on all occasions.

Deployments were conducted by the South West Rocks beach seine crew, operating under a permit issued under section 37 of the *Fisheries Management Act 1994* by I&I

NSW. After completion of the beach seine retrieval, researchers with the aid of an assistant and fishers, sorted catches into specific species; and recorded the area of capture within the seine gear.

Data were recorded on fish data boards, and transferred to waterproof data sheets. Data were collected on the total length (mm) and weight (kg) of individuals caught in the posterior wings and the bunt/codend. All wing data were measured in total, with bunt/codend catches sub-sampled on occasions where individual species totals exceeded 200 kg.

When excessive catches of predominantly juvenile fish were encountered, the codend was held in approximately one metre of water, and random sub-samples (three fish boxes or around 80 kg) were taken from the codend in fish washing baskets and the total weight estimated. The drawstring was then removed from the codend, releasing the remaining captured individuals and minimising mortality of juveniles.

Where conditions permitted, video footage, from both a land and underwater perspective was completed on both the modified and conventional nets to provide visual reference to the gear.

Statistical analyses that were conducted included:

- ANOVA of log (sample_total) to test for differences in total catches between net types and between species. The model was:

  sample_tot=constant.sp_abund.net_type.error .

- Standard Z tests to test for any differences between net types and between species in the proportions of legal sized fish.
- Logistic selectivity curves for each species-net type combination using cumulative proportion of each species

$$S_L = \frac{1}{1+\exp(a-b*L)}$$

where S_L is the cumulative proportion of number of fish caught by species with net-type combination at each mid-point length (L), a and b are constants.

Methodology of Part 2

Part 2 was designed to quantify the size selectivity of target species in the modified net (102 mm) using a net constructed entirely of 65 mm mesh of comparable dimensions. This latter net was termed the 'control' net and a covered codend methodology (see King, 2007) was planned.

The control net was deployed simultaneously outside, or surrounding, the modified net. The modified net was hauled first, followed by the control configuration. The hypothesis was that juveniles of the target species encircled by the modified net should be able to penetrate and escape through the larger openings in the modified configuration. These individuals would subsequently be captured in the control net (the frequency of which would be correlated).

Researchers and fishers anticipated completing deployments on travelling migrations (where conditions permitted) until the sample size and replicate requirements were reached.

Results

Results of Part 1

Total deployments

From the 29 April to the 8 May 2008, a total of 17 deployments, comprising seven and 10 deployments of the conventional and modified configurations, respectively, were completed using an alternate haul methodology.

Total catch

In total, 10 481 and 3 968 individuals were caught in the conventional and modified seines respectively; comprising three species, Yellowfin Bream, Luderick and Tarwhine. The total catch consists of individuals above the legal size limit (i.e. target catch) and below the legal size limit (i.e. bycatch).

The difference between net configuration for total number of fish retained per shot was highly significant (P<0.001), as was the difference between species (P<0.001). Figure 3 demonstrates the differences in average number of fish retained per shot (Yellowfin Bream, Luderick and Tarwhine of all lengths) by each net configuration (conventional and modified) and position in the net (codend/bunt and wings).

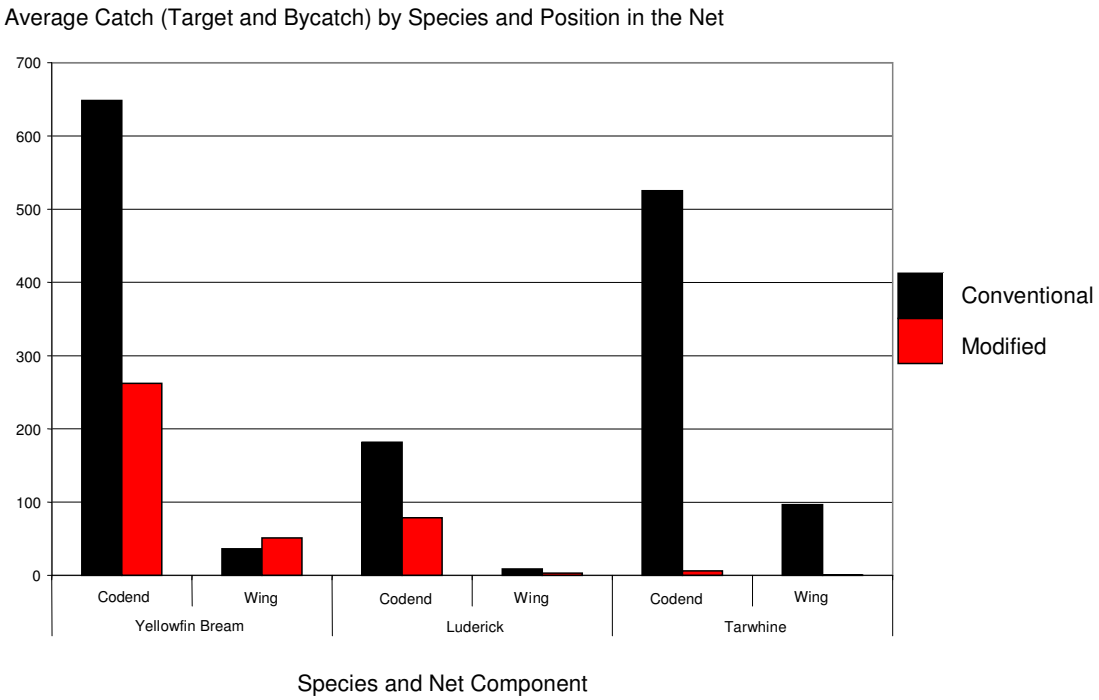

Figure 3 Average number of fish retained in the gear (target and bycatch) by species and position in the net for the conventional and modified beach seine configurations

Minimum Legal Total Length by species

In NSW, Minimum Legal Total Length (MLTL) has been regulated for most target species to allow individuals to reach reproductive maturity and spawn at least once before they may be retained. By regulation, all individuals below the MLTL must be released.

The MLTL for each species is:

- 250 mm for Yellowfin Bream;
- 200 mm for Tarwhine; and
- 270 mm for Luderick.

Proportions below MLTL for all species

In the conventional configuration, a total of 7 559 individuals comprising the three species, or 72.1% of the total catches (by number) were below the MLTLs. In comparison, only 369 individuals comprising the three species, or 9.3% of total catches (by number) in the modified seine were less than the MLTL. There were significant differences in the proportion of fish below the MLTLs for all combinations of species and position where caught (P<0.001) (Figure 4 and Table 1).

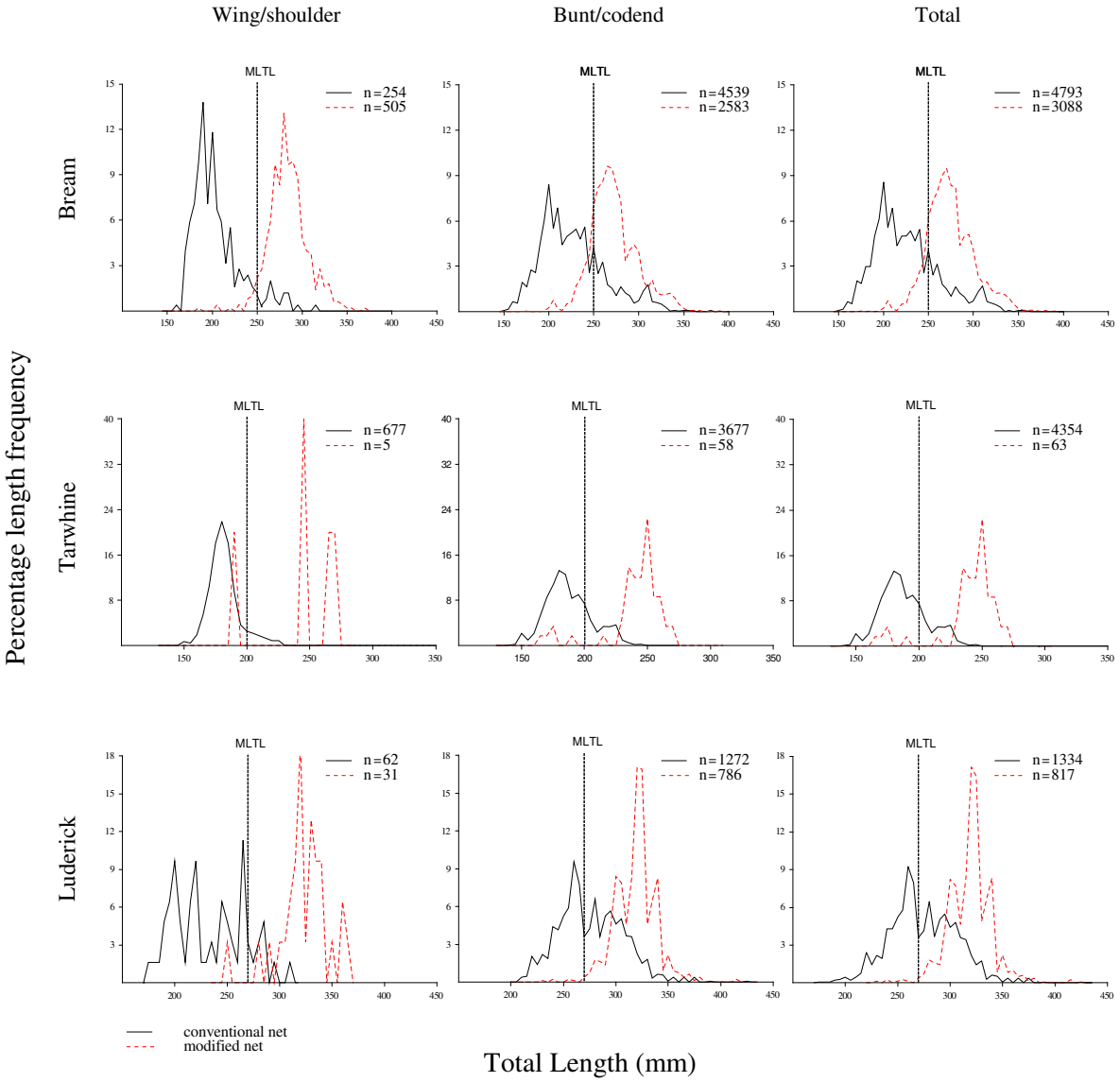

Figure 4 Percentage length frequencies of Yellowfin Bream, Tarwhine and Luderick caught in the posterior wings, bunt/codend and totals in the conventional and modified beach seine configurations

Table 1 Total number (No), % total catch of < or > MLTL for Yellowfin Bream (250 mm), Tarwhine (200 mm) and Luderick (270 mm) in the conventional and modified posterior wings, bunt/codend and totals (MLTL = Minimum Legal Total Length)

	Posterior Wings			Bunt/codend			Total Catch	
	No	% catch < or > MLTL	% total catch	No	% catch < or > MLTL	% total catch	No	% catch < or > MLTL
Conventional Bream < MLTL	232	91.3	4.8	3395	74.8	70.8	3627	75.6
Modified Bream < MLTL	15	3.0	0.5	341	13.2	11.0	356	11.5
Conventional Bream > MLTL	22	8.7	0.5	1144	25.2	23.9	1166	24.3
Modified Bream > MLTL	490	97.0	15.9	2242	86.8	72.6	2732	88.5
Conventional Tarwhine < MLTL	610	90.1	14.0	2691	73.2	61.8	3301	75.8
Modified Tarwhine < MLTL	1	20.0	1.6	5	8.6	7.9	6	9.5
Conventional Tarwhine > MLTL	67	9.9	1.5	986	26.8	22.6	1053	24.2
Modified Tarwhine > MLTL	4	80.0	6.3	53	91.4	84.1	57	90.5
Conventional Luderick < MLTL	52	83.9	3.9	579	45.5	43.4	631	47.3
Modified Luderick < MLTL	1	3.2	0.1	6	0.8	0.7	7	0.9
Conventional Luderick > MLTL	10	16.1	0.7	693	54.5	51.9	703	52.7
Modified Luderick > MLTL	30	96.8	3.7	780	99.2	95.5	810	99.1

Proportions below MLTL by position in the net

In total, 9.5% (by number) of the conventional seine total catches were retained (meshed or entangled) in the posterior wings with 90.0% of these individuals below the MLTL. In contrast, 13.6% of the modified seine total catches were (meshed or entangled) in the posterior wings, importantly only 3.1% of these fish were below the MLTL. No fish were caught in the anterior wings.

Proportion of Yellowfin Bream below MLTL

A total of 4 793 and 3 088 Yellowfin Bream were caught in the conventional and modified configurations, respectively. The optimum length of bream caught (or the most common length, i.e., mode) was 200 mm in the conventional net and 270 mm

in the modified net. In the conventional seine, a total of 3 627 or 75.7% of bream (by number) were less than the MLTL. A total of 5.3% of the bream catch were retained (meshed or entangled) in the posterior wings and 91.3% of these individuals were below the MLTL. In the modified seine, a total of 356 or 11.5% of bream were less than the MLTL. In total 16.4 % were caught within the posterior wings. In contrast, only 3.0% of these individuals were below the MLTL.

The majority of Yellowfin Bream caught in the conventional (94.7%) and modified (83.6%) seines were caught in the bunt/codend. Of these animals, 74.8 % and 13.2%, respectively, were below MLTL.

Selectivity curves plotted for Yellowfin Bream demonstrate substantially more undersized bream were caught in the conventional net compared with the modified net (Figure 5).

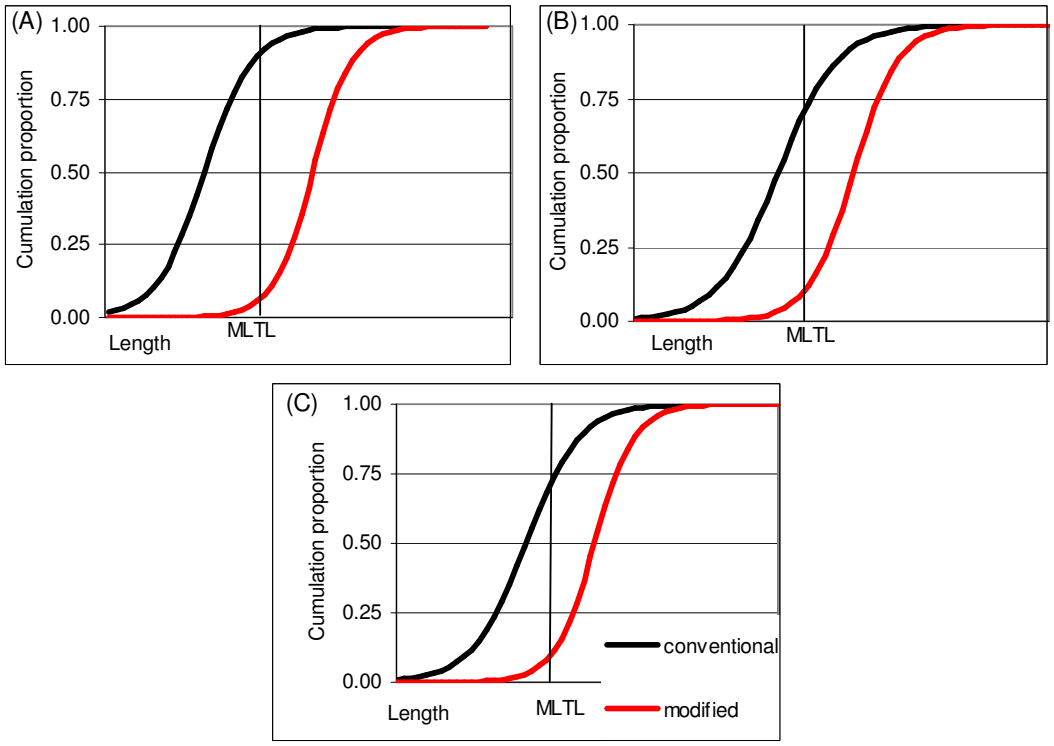

Figure 5 Logistic selectivity curve of cumulative proportion for Yellowfin Bream caught in the (A) posterior wings, (B) bunt/codend and (C) totals in the conventional and modified beach seine configurations (black is conventional and red/grey is modified)

Proportion of Tarwhine below the MLTL

A total of 4 354 and 63 Tarwhine were caught in the conventional and modified configurations, respectively. The optimum length of Tarwhine caught (or the most common length, i.e., mode) was 180 mm in the conventional net and 250 mm in the modified net. In the conventional seine, a total of 3 301 or 75.8% of total Tarwhine (by number) were less than the MLTL. In total 15.5% of the Tarwhine catch in the conventional gear were retained (meshed or entangled) in the posterior wings and 90.1% of these individuals were below the MLTL. In the modified seine, a total of 6 or 9.5% of Tarwhine (by number) were less than the MLTL. In the modified seine, a total of 5 individuals or 7.9% of the Tarwhine caught were retained within the posterior wings. Only one individual Tarwhine was below the MLTL.

The majority of Tarwhine caught in the conventional (84.4%) and modified (92%) seines were caught in the bunt/codend. Of these animals, 73.2 % and 8.6%, respectively, were below MLTL.

Selectivity curves were not plotted for Tarwhine due to lack of data.

Proportion of Luderick below the MLTL

A total of 1334 and 817 Luderick were caught in the conventional and modified configurations, respectively. The optimum length of Luderick caught (or the most common length, i.e., mode) was 260 mm in the conventional net and 320 mm in the modified net. In the conventional seine, a total of 631 or 47.3% of total Luderick (by number) were less than the MLTL. In total 4.6% of Luderick catch from the conventional configuration were retained in the posterior wings. Significantly 83.9% of these individuals were below the MLTL. In the modified seine, a total of seven individuals or 0.9% of total Luderick (by number) was less than the MLTL. In total, 31 individuals or 3.8% of Luderick catches were retained within the posterior wings. One Luderick was below the MLTL.

The majority of Luderick caught in the conventional (95.3%) and modified (96.2%) seines were caught in the bunt/codend. Of these animals, 45.4 % and 0.8%, respectively, were below MLTL.

Selectivity curves for Luderick demonstrated that substantially more undersized Luderick were caught in the conventional net compared with the modified net (Figure 6).

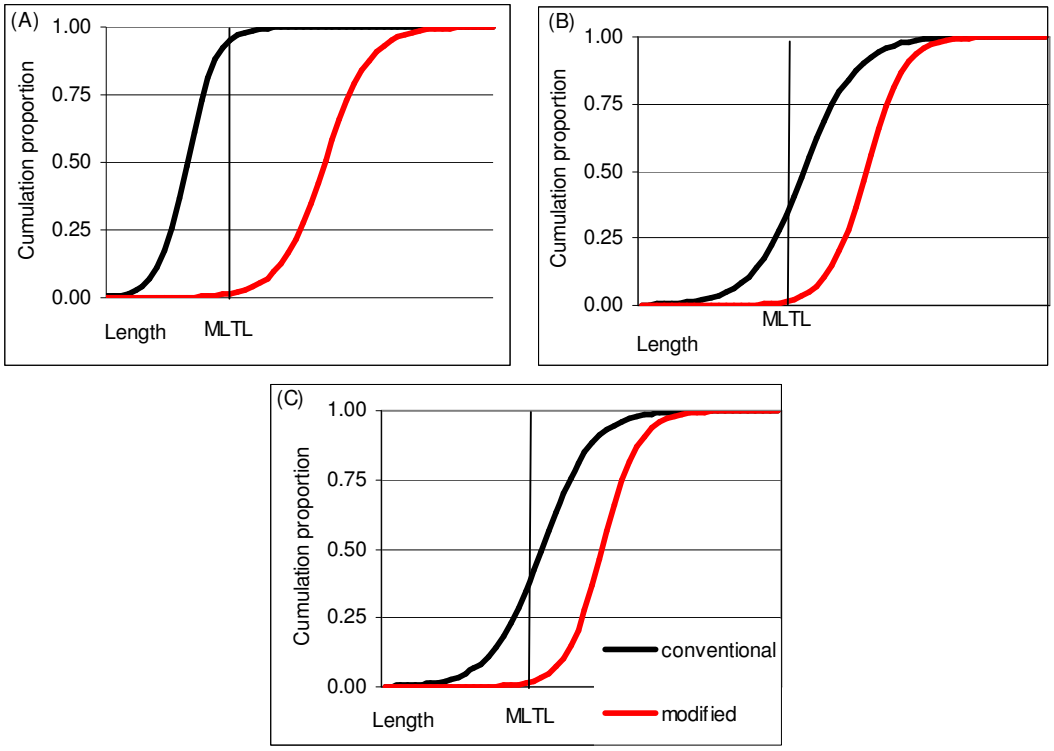

Figure 6 Logistic selectivity curve of cumulative proportion for Luderick caught in the (A) posterior wings, (B) bunt/codend and (C) totals in the conventional and modified beach seine configurations (black is conventional and red/grey is modified)

Percentage reduction in fish below MLTL by species

The percentage of Yellowfin Bream, Tarwhine and Luderick caught throughout the entire configuration, less than the MLTL, was reduced by 64 %, 66 % and 47 % respectively, using the modified seine configuration.

Underwater and operational observations

Underwater digital recording and visual observations of conventional and modified seines during hauling operations highlighted a number of behavioural responses of ground fish species when enclosed within a beach seine net.

Of particular interest was the herding behaviour of enclosed ground fish species. Fish were observed to herd in front of the mouth of the seine, and nearing completion of the seine retrieval, were subsequently directed towards the codend. The majority of escape attempts were observed in these later stages of the seine retrieval. Juveniles of the target species were observed to successfully penetrate and escape through the meshes of the bunt/codend and posterior wing sections of the modified seine configuration.

A number of benthic species including Sand Flathead (*Platycephalus spp*), and various flounder (*Pseudorhombus spp)* and stingarees (*Trygonoptera spp*) were observed to bury in the substrate, allowing the footrope to pass over and prevent capture.

Yellowfin Bream and Tarwhine were observed grouping and stalling in substrate deviances and holes, often positioning in the lateral plane to allow the footrope or leadline of the seine to pass over, resulting in successful escape. On various occasions fish were watched following their escape from the nets. No juvenile mortalities were observed due to escape, with many individuals re-grouping shortly after escape from the gear.

The participating fishers noticed that the modified gear was physically able to be retrieved more easily. The obvious reason for this is that the modified net (with the larger mesh) allows water to pass through the meshes more easily and so offers less resistance. All seine deployments were retrieved at around 0.8 metres/second irrespective of which net was used.

Results for Part 2

Part 2 was not completed due to the temporal and seasonal variations of migratory ground fish species. Migrations of the targeted species ceased and therefore further experimental deployments utilising a control net (acting as a cover net) could not be achieved. In addition there were concerns regarding fish behaviour noted during underwater observations during Part 1. Adult and juvenile fish were observed escaping under and over the footrope and headrope, which may have biased a covered codend methodology.

Discussion

Anecdotal evidence suggests that following flood events non-spawning (industry termed 'hard-gut' or 'wash out') migrations can occur. These migrations generally consist of fish with limited or no gonad development. The influx of fresh water into the estuaries may influence large numbers of fish to prematurely migrate out of the estuaries into the ocean. These migrating schools are generally comprised of mixed fish species of varying size classes. Similarly, published data describing the catches of commercial beach seines deployed in NSW estuaries indicate significant proportions of the catch may comprise juveniles of the targeted species (Gray *et al*., 2000; Kennelly and Gray, 2000).

The appropriateness of the enforced mesh sizes in selecting catches of legal sizes and simultaneously releasing undersized fish is unknown due to the limited data available describing catch characteristics in the beach seining operations of the NSW Ocean Hauling Fishing. The legislated legal mesh sizes, established in the 1940's, and still applied to commercial beach seines at the time of the trials, were derived from industry developed gears and practices that were common when particular fisheries became established, and additionally through the mesh sizes that were commercially available at the time of determination (Broadhurst and Kennelly, 1995; Gray *et al*., 2000).

The regulated beach seine gear configuration has been assessed in terms of the transverse morphology, or maximum girth, of the targeted species; in relation to the available mesh openings of the currently legislated mesh sizes. Previous analyses of key target species captured in NSW ocean beach seine operations describe the predicted girth of the three key ground fish species, Yellowfin Bream, Luderick and Tarwhine, at various length classes. Assessment of the relationship between the MLTL and predicted girth described the inappropriateness of the existing regulations with respect to mesh sizes (Wooden, 2007).

A study examining an increase in mesh size (from a minimum of 50 mm to 102 mm in the bunt/codend section of a conventional beach seine configuration) indicated that during periods where sea mullet are not targeted, increasing the mesh size in the bunt/codend would be beneficial in reducing the catches of juvenile target species (e.g. Yellowfin Bream and Luderick) whilst maintaining adult targeted catches. However, this experiment concluded that the posterior wings had a strong contributory influence on the total catch composition, and therefore could provide additional benefit from an increase in mesh size (Wooden, 2007).

The present study illustrated the benefits of increasing mesh sizes throughout the entire net configuration for reducing the capture of juvenile ground fish species, where present, in beach seine catches. Underwater observations and film indicate behavioural variation amongst species. Fish such as Sand Flathead, and various flounder and stingarees were visually observed burying into the substrate moments before the leadline approached them and none were captured in the study. Underwater filming illustrated the ability of Yellowfin Bream, Luderick and Tarwhine to group and stall in holes and gutters in the substrate, and swim horizontally to escape the passing leadline. It was also observed, that during a typical seine deployment, these species may make multiple attempts to escape, in a frantic or passive nature. The behaviour displayed was often variable amongst the different schools targeted, although during the final stages of the retrieval process, the majority of individuals enclosed attempted to escape more frequently. Fish were

observed to penetrate and escape through the meshes throughout the entire hauling process, and visually observed escaping through the posterior wings, and through the top, bottom and sides of the bunt/codend.

These results should only be used to gauge the effectiveness of each net's ability to reduce the retention of juvenile target species and should not be used to compare total catch volumes and landings. This is due to each shot being conducted on alternate travelling schools that varied in overall biomass, species and/or size composition.

The bunt/codend of both configurations retained the most significant proportion of Yellowfin Bream, Luderick and Tarwhine catches. The percentage frequency of Yellowfin Bream smaller than MLTL caught in the total modified configuration was substantially reduced from 75.7% to 11.5%. The posterior wings in the modified configuration retained a greater proportion of Yellowfin Bream catches (16.4%) than the conventional configuration (5.3%). The increase in meshed or entangled individuals is more than compensated for by a substantial reduction in fish less than MLTL, from 91.3% in the conventional to 3.0% in the modified posterior wings.

The total number of Tarwhine captured in the modified seine was significantly less than the conventional seine. This may be attributed to the differences in morphology, i.e. maximum girth of Tarwhine compared with Yellowfin Bream, for which the mesh size was specifically chosen. Broadhurst *et al.* (2006) estimated that the appropriate mesh size for Tarwhine is between 78 and 81mm. Although the numbers of Tarwhine caught in the modified seine were reduced, this may also be indicative of the variable size and variable species compositions encountered during the study. Nevertheless, the percentage frequency of Tarwhine smaller than MLTL caught in the total modified configuration was substantially reduced from 75.8% to 9.5%. The percentage of total Tarwhine less than the MLTL in the posterior sections of the conventional seine equalled 90.1% in comparison with 20.0% in the modified seine. In total, 677 and 5 individuals less than the MLTL were caught in the conventional and modified posterior wings, respectively. Although the bunt/codend retained the most significant proportion of Tarwhine in both seine configurations, the percentage of individuals less than the MLTL (73.2%) was considerably different to that of the modified gear (8.6%). These results indicate the regulated mesh sizes are inappropriate for reducing the capture of juvenile Tarwhine. However, the results also indicate the mesh size may be too large to retain the majority of individual Tarwhine greater than the MLTL.

Similarly, the percentage frequency of juvenile Luderick was reduced using the modified seine configuration. The conventional configuration comprised in total, 47.3% of individuals less than the MLTL. This significantly differed from the modified configuration which comprised in total, 0.9% of individuals less than the MLTL. The bunt/codend retained the most significant proportion of Luderick catches, for the conventional and modified beach seines, 95.4% and 96.2%, respectively. The posterior wings accounted for 4.6 % and 3.8% of total Luderick catches. A significant reduction of juvenile Luderick was evident in modified posterior wings, the percentage of undersize individuals in these areas equalled 83.9 % and 3.2%, respectively.

Benefits and Adoption

The primary beneficiaries of this research will be the fishers of the NSW Ocean Hauling Fishery. The fishers had been lobbying for legislation changes in the regulated maximum mesh size in the Hauling Net (general purpose) for many years, but they needed the scientific evidence to support their ideas derived from extensive experience in the industry. Their perseverance has paid off.

As a consequence of this and previous research demonstrating that an increase in mesh size (to 102 mm) can help to reduce the capture and mortality of juvenile ground fish, the maximum allowable mesh size in the bunt/codend of the Hauling Net (general purpose) was increased from 65 mm to 102 mm on 1 April 2010.

Fisheries Management (Ocean Hauling Share Management Plan) Regulation 2006

Current version for 1 April 2010
Part 6A Fishing Gear
13A Hauling Net
Table Hauling Net (general purpose)

Waters-Ocean waters within 3 nautical miles of the natural coast line including the waters of Coffs Harbour.

Description of net-

(i) from 1 March to 31 July in each year—Total length not exceeding 400 metres; length of bunt not exceeding one-third of the total length of net; mesh of bunt not less than 50 mm nor more than 65 mm if taking any fish in the fishery or not less than 95 mm nor more than 102 mm if taking fish other than sea mullet (*Mugil cephalus*); mesh of wings not less than 65 mm nor more than 86 mm; no rings or other devices attached to net (including on lead line) that facilitate the pursing of the net,

(ii) during any other period—Length of bunt not exceeding one-third of the total length of net; mesh of bunt not less than 50 mm; mesh of wings not less than 80 mm; no rings or other devices attached to net (including on lead line) that facilitate the pursing of the net

http://www.legislation.nsw.gov.au/maintop/view/inforce/subordleg+736+2006+cd+0+N

As a result of these changes there may be benefits to the biomass of the species of concern, and consequently to the sustainability of the commercial and recreational fisheries. This will be mainly attributed to the expected reduction in the capture of juvenile target species (bycatch) as a result of individuals escaping unharmed during the hauling process. Additional benefits to the commercial fleet may be improved sorting efficiency and handling practices.

The NSW Ocean Hauling Fishery has proactively addressed juvenile target species bycatch concerns. The results and conclusions should be extended to the general public, which may help to alleviate some misconceptions concerning the professional fishing industry.

Further Development

Fishers and scientists are continuously refining fishing technologies to further reduce bycatch, improve target catch rates, promote sustainable fish stocks and by default, sustainable fisheries. This process is expected to continue in the NSW Ocean Hauling Fishery, although with changes in mesh size regulations, there should be a considerable delay in further research of this type until the impact of such modifications can be adequately assessed.

A research need for this fishery that is worthy of further development is an improvement in product quality through modifications to handling operations. Following capture, the codend is hauled onto the beach to facilitate the sorting of catches and removal of incidental juvenile catches. On occasions, fish may be damaged as the net is hauled onto the beach resulting in reduced product quality. Future research examining further modifications to gear and/or alternative handling techniques may help to reduce these impacts and improve the profitability of the fishery.

Planned Outcomes

The planned outcome achieved to date is the provision of data to fisheries managers that demonstrates the effectiveness of a simple increase in maximum mesh size in the Hauling Net (general purpose) configuration to reduce the capture and mortality of juvenile ground fish species targeted during the 1 March to 31 July season.

The ultimate outcome is an improved survival rate of fish below the MLTL of these commercially and recreationally important species, and consequently, a more sustainable and publicly-accepted fishery.

Conclusion

In order to mitigate against the unnecessary mortality of juveniles, commercial seine fishers should have access to a range of mesh sizes to target and capture a range of species and sizes throughout various times and locations. This would be similar to arrangements currently provided by I&I NSW with minimum mesh size configurations legislated for a number nets used to target species, including Australian Sardine (*Sardinops neopilchardus*), Australian Anchovy (*Engraulis australis*), Sandy Sprat *(Hyperlophus vittatus*) and Eastern Sea Garfish (*Hyporhamphus australis*).

This study highlights the effectiveness of increasing the mesh size in the Hauling Net (general purpose) used in the NSW Ocean Hauling Fishery, from a maximum of 65 mm to 102 mm, in reducing the incidental capture and mortality of juvenile Yellowfin Bream, Tarwhine and Luderick. This modification is only appropriate at specific times of the year and in areas where a significant number of juveniles are present in the catch. The modified net (102 mm mesh size throughout the net) caught substantially fewer fish less than the legal length (MLTL) compared with the conventional configuration with a maximum of 86 mm, 65 mm and 65 mm mesh size in the anterior wings, posterior wings and bunt/codend, respectively.

This significant reduction is beneficial to the species biomass and the sustainability of the fishery as a whole through the release of juvenile fish. Minimising the capture of juvenile target species will also reduce the time fishers expend sorting catches; improving efficiency by decreasing the time required to remove any remaining juveniles from the catches, hence improving their survivability. These benefits may additionally help to alleviate conflict between commercial and recreational fishers.

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Appendix 1 Intellectual Property

There are no recognised intellectual property issues arising from this research.

Appendix 2 Staff

Principal Investigator	Michael Wooden (OceanWatch Australia)
Co-investigator	Dave Cranston (OceanWatch Australia)

Initially these roles were reversed; however, staff changes within OceanWatch over the course of the project necessitated the change.

Appendix 3 List of Tables and Figures

Appendix 4 Photos

Fisherman's Hut at Trial Bay, South West Rocks

Vince Jr spotting for schools of fish

Vessel launch

Deploying the net

Beach seine sample of catch

Re-loading the net