ERGONOMIC SOLUTIONS AND ORGANIZATIONAL MEASURES ADDRESSING THE NEED FOR A REDUCTION IN RISK FROM BIOMECHANICAL AND WORKING OVERLOAD IN THE FISHING SECTOR OF MARCHE REGION

1. Organisations involved

- Single Regional Health Agency for Marche, Territorial Zone 7, Prevention and Safety Service in Work Environments, Ancona.
- Research Unit for Ergonomics, Posture, Movement (EPM)- Fondazione Don Carlo Gnocchi –ONLUS- Milan.
- Istituto Superiore Prevenzione e Sicurezza sul Lavoro (ISPESL), (National Institute for Occupational Safety and Prevention).

2. Description of the case

2.1. Introduction

In 2004, the Single Regional Health Agency for Marche, Territorial Zone 7 of Ancona, in collaboration with ISPESL in Rome and EPM in Milan, completed a research study on the evaluation of risks in the manual handling of loads, awkward postures and repetitive movements of upper limbs in the region's fishing sector.

Risk analysis was conducted on 7 fishing vessels, which were employed in the most common types of fishing in the Marche area: three fishing vessels with fixed opening equipment called "rapid", two that were used for towing a "loose" net, one used for towing a "dragnet" and one used for "mussel" dragging.

The "rapid fishing vessels" are so called because they are equipped with "rapid nets" which consist of a net connected to a rigid bar with combs attached'.

The vessel is equipped with 4 "rapid" devices which are dropped into the sea and dragged along the seabed. This fishing method catches various types of fish, molluscs and crustaceans, but also considerable amounts of debris. The crew consists on average of four seamen, the engineer and the captain.

Figure 1. A "rapid" device

The vessels towing the “loose” net work in pairs, fishing for “blue fish”; the net is cast and towed alternatively on one of the fishing vessels. The vessel has a six/seven person crew, one of whom is the captain and one the engineer.

Figure 2. A loose net

The vessels towing the “dragnet” are equipped with a long net dragged on the seabed and consisting of two separate parts: the upper part contains mainly fish, molluscs and crustaceans, while the lower part contains debris and mud. The vessel has a two-person crew, the captain and the engineer.

Figure 3. A dragnet

The “mussel” equipment is located on the bow and consists of a dredger and a collection tank connected to a sieve by a screw for sorting the mussels. The larger mussels are placed in bags and sent to the market, while the small and medium size shellfish are thrown back into the sea. The vessel has one captain and one engineer.

Figure 4. A mussel device

Monitoring was conducted directly on-site using digital video cameras to record a typical working day. The recorded footage was used to study the organisation of work, analyse the work cycle phases (casting, towing, transport, washing, sorting, packing, unloading) and analyse the risk factors, tasks and technical actions, describing, numbering and timing the movements and operations as they occurred.

This research study has shown aspects of “poor ergonomics” and “poor organisation” in the methods of fishing studied, and has resulted in improved knowledge concerning the risk from biomechanical overloading of the upper limbs and the neck and spine, in a sector so important at the local level but still rather “ignored” at the national and international level.

Direct participation in the fishing process and the exchanging of ideas and experiences with crewmembers was an indispensable resource for the vessel redesign and the application of ergonomic solutions.

For risk analysis, the following models of evaluation were applied: the NIOSH[1] tool for the manual handling of loads and the OCRA[2] checklist for the repetitive movements of the upper limbs.

For the evaluation of the risk from manual handling of loads, the durations of the single operational phases were timed and the number of workers involved in each phase was counted. The frequencies by which the various manual handling operations were undertaken and the consecutive duration over which they were carried out were measured. The weight and type of each load handled and the weight of the load handled by each worker for each phase were then measured.

To complete the evaluation of the risk from the manual handling of loads, an evaluation of horizontal transport operations for different loads using Snook and Ciriello[3] tables was then carried out. Snook and Ciriello tables define the recommended maximum effort in relation to

gender, frequency of action, movement and height of hands from the ground. These were applied to the evaluation of the push and pull actions used in manual transportation.

For the risk analysis of repetitive upper limb movements, the technical actions, recovery time, frequencies, the use of force and the posture were then identified and evaluated. The Methods-Time Measurement (MTM-UAS)[4] method was used to study the operations for the sorting of the catch, evaluating whether the working speed used in performing the task was coherent with respect to the times suggested by this method, and to determine the performance level of the crewmembers and the distribution of recovery time actually used. The MTM-UAS represents a second generation of synthesized data, based on the MTM-1 system. It was constructed through the statistical analysis of basic MTM-1 motion patterns. This system is best suited for use in environments which exhibit the characteristics of batch production. It is a procedure for *improving methods* and *establishing time standards* by recognizing, classifying, and describing the motions used or required to perform a given operation and assigning pre-determined time standards to these motions.

The study of the “loose net” showed the main hazards to be connected with the handling of heavy loads (medium/high risk in the phases of collecting the fish from the stern area, transport and unloading of the packed product).

The study of the “dragnet” and “rapid” systems has identified the main hazards as those connected with biomechanical overloading of the hand and of the wrist (medium risk) for the presence of rapid movements of pinch grasping with both hands (taking and positioning). Repetitive work is linked with operational phases such as the selection of the catch and the preparation of the boxes, which take up most of the time.

On the “mussel boat”, the only phase actually involving overloading of the spinal column was the one characterised by dumping all the medium and small size mussels into the sea.

The presence of unsuitable postures, especially of the spinal column (back bent almost to maximum limit) was most prevalent during the mussel-sorting phase which took place on the stern of the “dragnet” and “rapid” vessels.

2.2. Aims

The results obtained by the risk analysis on the manual handling of loads, awkward postures and repetitive movements of upper limbs have highlighted a need to seek solutions for some basic operations that could meet the following requirements:

- Reduce the awkward postures (back bent almost to maximum limit in the “rapid” systems during the fish sorting phase)
- Reduce the handling of catches that overload the spinal column (in the “loose” system during the phase of collecting the catch after emptying the contents of the net onto the deck).
- Reduce the repeated handling of the same load (shifting of full baskets and cases) in various parts of the vessel and for the continuous operations of washing the catch and for the stowing and piling of the finished cases. (Due to the lack of space on the fishing vessel, and the impossibility of keeping stable stowing platforms which would obstruct movements, the items are handled several times during a journey).
- Eliminate the practice of dumping waste directly into the sea in order to avoid the repeated cleaning of the deck and the fishing vessels, and to reduce the risk of falling due to slipping. (The “catch,” in fact, includes a considerable amount of waste products consisting of species of fish which are non-comestible or without commercial interest. The “dirt” mixed with sand, debris and residue of all types often accumulates on the deck of the vessel).

2.3. What was done, and how?

Three improvements have been made: the first two on “rapid” fishing vessels with fixed opening equipment and the third on a vessel towing the “loose” net.

1st Fishing vessel with fixed opening equipment (“rapid”)

Given the availability and interest of the owner of one of the vessels tested, a new feature was developed which consisted of setting up a platform in the stern zone that could be lifted and tipped by hydraulics, and after reaching a height of about 80 cm allowed personnel to undertake the initial catch selection operations whilst standing with their backs straight.

This tipping platform was designed to lift simultaneously the load contained in the four “rapid” devices or in a large bag, with adjustable height so that fishermen could work with their back straight during sorting.

Figure 5. Selection of the catch astern: before and after the installation of the stern platform

The tipping platform is operated by hydraulic pistons providing the necessary support. Thanks to the simplicity of the application and its cost, the solution was soon adopted by many “rapid” fishing vessels in the Ancona area.

2nd Fishing vessel with “rapid” fixed opening equipment

In 2005, when a new fishing vessel was commissioned, all the improvements proposed for the sorting, washing, transport and packing phases of the catch became part of the executive design.

Apart from the adjustable stern platform already provided in the 1st fishing vessel, a continuous structure was created consisting of a belt system carrying the catch from the raised tipping platform (P) to the area where the cases are prepared.

This structure consists of a loading belt (K**)** that receives the catch from the lateral tipping of the stern platform. The product is thus already “removed” at the stern zone.

The washing belt (Y) is inclined, equipped with “supports” for loading, and handles the same volumes brought by belt (K).

The sorting belt (J) is flat and handles the same volumes brought by belt (Y); the structure of the belt allows permeability for the washing flows created by the percolation of residues. It is easy to clean, designed for contact with food products and has deflectors (F) for the automatic elimination of residues.

The last part consists of selector (S) of product residues; it is flat and handles much smaller loads with respect to belt (J) and runs in a sheltered area.

Figure 6. Fishing vessel with "rapid" fixed opening equipment (aerial plan)

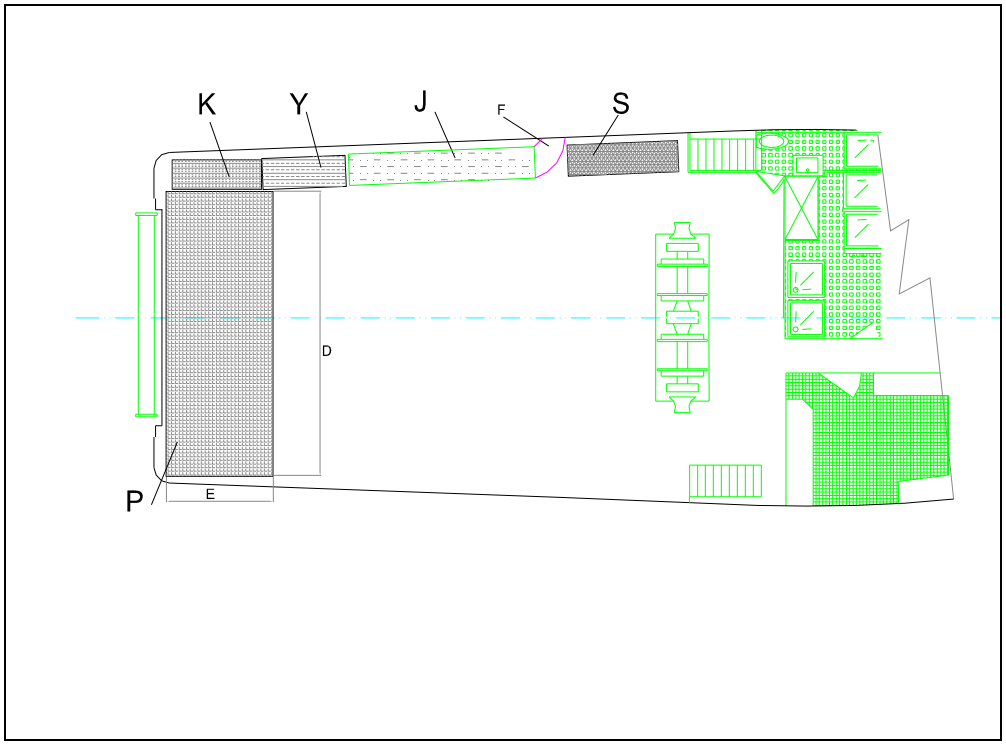
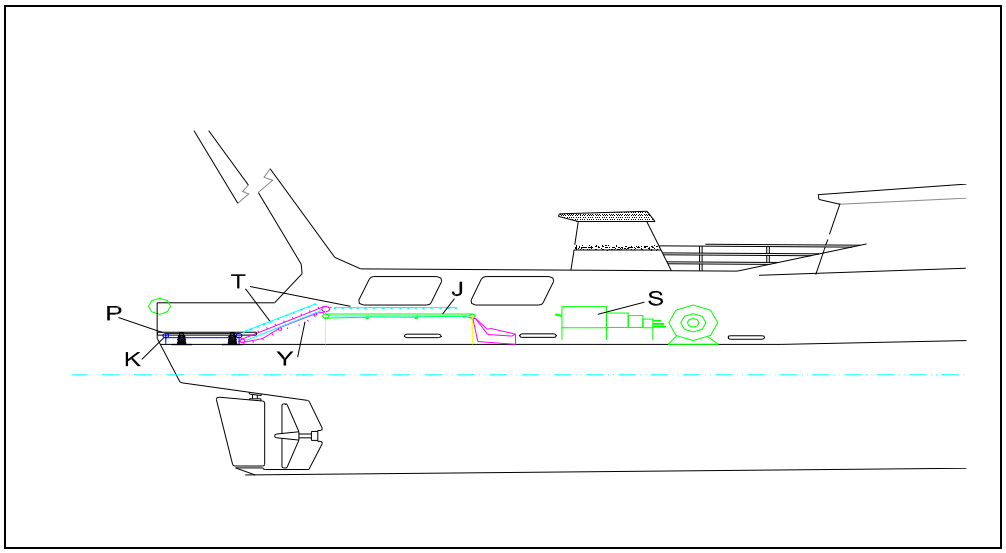


Figure 7. Fishing vessel with "rapid" fixed opening equipment (horizontal plan)



It was also necessary to study mechanisms for continuous irrigation of the catch and to create drainage canals for the continuous flow of water to make the phase of debris removal faster and more effective and without it coming into contact with the deck surface.

Due to mechanical pressure on the whole line, the machines must be secured permanently to the supporting structure of the vessel's deck.

The system has a rather complex geometry which required considerable study and numerous practical applications before the final morphology could be achieved.

With regard to the plant, a stop button was provided for use in case of a need to isolate the pump of the hydraulic circuit.

The speed of the belt can be changed at any time by the workers: in general after loading part of the conveyor belt, it is stopped until sorting is completed.

The cases used for packing were placed in front of the worker sorting the catch, thus reorganising the workflow of the packing phase. Previously, the lack of space on the fishing boat often lead to “untidiness” that required workers to have unsuitable spinal postures.

Figure 8. The redesigned line in its entirety from the stern platform to the various conveyor belts to the direct dumping overboard of the debris with operators present

Finally, the solutions applied to the vessels fishing with “rapid” equipment have been validated from an ergonomic point of view to verify the usefulness and effectiveness of the improvements made. In order to achieve this, three different types of “rapid” layout have been compared:

- Two redesigned vessels (1st Fishing vessel partially redesigned and the 2nd one completely redesigned)
- An unaltered “rapid” boat.

The ergonomic and organisational comparison is based on the analysis of the following organisational aspects of the three differently outfitted boats: the work and rest times of the crew, the number and times of the journeys and casting of nets, cycle times, waiting time between journeys, total duration of the journey, duration of the sorting and packaging phase, number of operators deployed in each phase, number of cases and sacks prepared for each catch.

It was not possible to make a detailed comparison of each organisational factor due to the differences observed during the journeys with the three fishing vessels (different duration of the fishing session, different duration of the interval between casting of nets, different number of “castings/journeys” made and analysed, different fishing zones and therefore different quantity and quality of the catch, and different organisational characteristics of single captains/owners). It is in any case useful to highlight some results containing evidence of the effectiveness of the redesign measures applied.

By comparing the organisational data obtained following the analysis conducted during inspections on the three different types of “rapid” vessel, the results can be summarised as follows:

- On the unaltered vessel, the study has shown that between journeys, crewmembers cannot take breaks unless sailing times are reduced. In this case they are often unable to finish the work carried out whilst sailing which therefore accumulates with each successive journey, reducing rest times for personnel (4 crewmembers are employed in the fish handling process) and increasing the speed with which they have to conduct the sorting, leading to lower productivity and the production of more waste.

- On the partially and completely redesigned "rapid" boats, the study has demonstrated the possibility of using the pauses between journeys and often only 3 crewmembers are required for fish handling (in a shift system with one crewmember resting); the distribution and size of recovery differed according to the extent of redesign. Sorting times were shorter and rest shifts, including meal breaks, have been maintained.

3rd fishing vessel towing a "loose" net

One of the most tiring working phases of the "loose" net system proved to be the collection of the catch from the stern platform where the "bag" (net full of blue fish) is opened. The fish is collected with baskets and carried to the bays through a series of stages that can be eliminated to improve conservation of the catch and to eliminate handling and shifting of loads. The "loose" system is the type of fishing in which special care is required because blue fish deteriorates easily, and which should therefore be "handled" as little as possible, and which needs to be constantly cooled (with ice or ice water).

The redesigned boat was equipped with two large tanks or bays: one secured to the stern area and the other, mobile one, positioned on the side of the vessel, running if necessary along a rail, reaching the position opposite the fixed bay. There were also smaller manual bays only used when necessary, i.e. in case of a larger catch.

With the positioning of the bays in a stable and mobile form (according to the catch size) the phase of opening the bag on the aft deck surface is completely eliminated, thus also eliminating the phase of collecting the fish with the use of baskets that weigh approximately 30 kg each; the analysis of that phase with the NIOSH method resulted in a significant hazard level for the spine.

Figure 9. The collection of the catch astern before (A) and after (B) the improvements

2.4. What was achieved?

With the complete redesign of the first and second "rapid" fishing vessels with fixed equipment, overload of the lumbar region was reduced for the workers and they were also less exposed to the weather since sorting now takes place in a sheltered area.

The accident hazard rate was also improved by the overall redesign of the sorting system and automatic washing of the catch.

From the viewpoint of work organisation, the following factors were improved:

- Recovery time between journeys due to longer cycle times and the possibility for crewmembers to rest between shifts.
- Sorting times were reduced due to the continuous watering system that cleans the catch and makes it easier to see, thus making selection easier.
- The time dedicated to cleaning the deck surface was considerably reduced since the line is equipped with direct discharge into the sea of debris and thus it is no longer necessary to continuously wash the stern area and, after completion of sorting, only brief cleaning for the small amount of waste still present is required. The deck surface is thus safer because it is less slippery.

The quality of sorting has also improved; the catch is pre-washed and distributed in a thin layer across the belt, making the various species and rejects easier to spot. The quantity of fish and molluscs selected is greater, with the consequential increase of productivity; there was a reduction of losses of "good" fish, sometimes discarded because it is mixed with debris**.**

On the redesigned fishing vessels with "loose" nets there was a significant advantage in terms of time and fatigue:

- In terms if time, since the sardine fishing session lasted for a total of 9 hours (compared to the 12 hours for a boat that is not redesigned) and generated a similar amount of packaged final product.
- In terms of fatigue and health risk, with elimination of the phase of handling loads weighing 30 kg which together with the other factors involved in the lifting action, posed a considerable hazard.

Finally, the first health surveillance outcomes led to some benefits for the upper limbs of workers in the specific sector. However, accurate quantitative outcomes cannot be determined until several years after implementation.

2.5. Problems faced

The main problems faced were a result of the particular nature of the sector whereby health and safety interventions are often merely viewed as interference. On the other hand, in cases where the captain welcomes such interaction, the crew will participate willingly out of respect for the captain.

Another problem related to the Harbour Office, which controls the authorisation of trips out to sea. In conclusion, there were no technical problems, simply difficulties resulting from the way the sector has developed and from the authorities regulating the sector.

2.6. Success factors

The main success factors have been the direct participation of workers and ship-owners and the strong involvement of the sectoral employers' organizations

The world of fishing, though linked to very traditional values, feels the need to undertake competitive "modernisation" and to improve product quality.

The sector also enjoys various forms of funding, including:

- funds for modernisation to improve safety on the fishing vessel
- incentives to operators in the sector to favour processes of improvement in the quality and health characteristics of fish production.

The implementation of the organisational and structural changes proposed is associated with the search for solutions to the most pressing issues in the Sector:

- improvement of the catch with commercial and economic benefits;
- reduction of the "fatigue factors" and of risks for health and safety in order to reduce absences due to accidents and sickness;
- lack of manpower available for reasons related to the especially fatiguing type of work and frequent use of foreign workers.

The implementation of the improvements proposed for the three vessels has been easily applied thanks to the sensitivity and willingness of the owners, but also because of the possibility to recoup costs and improve productivity due to:

- the improvement of the quality of the product which, being less handled, looks "healthier" and becomes more competitive;
- better quality working conditions help vessel owners to retain crewmembers and avoid high staff turnover, sickness and the associated bureaucratic, organisational and economic difficulties.

2.7. Further information

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2.8. Transferability

The technical solution adopted in the first case (fishing vessels with fixed equipment or "rapid" type) has been applied to many "rapid" vessels in the Ancona area (about 60%) thanks to the simplicity of the application, the cost and the possibility of using dedicated sector funds for modernisation of equipment.

The technical solution used in the third case (fishing vessels towing the "loose" net) is highly accessible in terms of cost, simple design and technical feasibility without impact on the stability of the vessel, while producing considerable advantages.

The redesign conducted in the second newly build "rapid" vessel was definitely more expensive and complex compared with the modifications to the other vessels, which only underwent partial modernisation.

An overall construction design concept is required, in which the technical aspects must be associated with economic and financial compatibility and with the verification of the profitability of the investments.

It is therefore feasible for ship owners who intend to plan a fishing enterprise and for the shipbuilding firms in the sector.

3. References, resources:

1. NIOSH lifting equation:
http://www.cdc.gov/niosh/docs/94-110/ (accessed 29/10/10).
2. OCRA Checklist:
http://www.epmresearch.org/documenti/checklist_ocra.pdf (accessed 29/10/10).

3. Snook and Ciriello tables:
http://www.ergonomiesite.be/links/snook_tabellen.pdf (accessed 29/10/10).
4. Methods-Time Measurement (MTM-UAS) analysis:
http://www.mtm.org/systems.htm (accessed 29/10/10).

Further reading:

- www.ispesl.it (accessed 27/10/10).
- www.legapesca.coop (accessed 27/10/10).
- www.federpesca.net (accessed 27/10/10).
- www.federcoopesca.it (accessed 27/10/10).
- www.ismar.cnr.it (accessed 27/10/10).
- www.imo.org (accessed 27/10/10).