Future fishing vessel technologies: challenges for a sustainable European fishing fleet
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Analysis of energy use in Italian fishing vessels

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Rationale: crisis of fishing industry

Main factors affecting fishing industry	Influence on fishing activities
➢ Overfishing ➢ World economic crisis (fishermen do not have any influence in the market)	**Revenue**
➢ Increasing in fuel price ➢ Fishing vessels not efficient usually because of outdated technology	**Costs**

Profitability Index

$$I = \frac{Revenue}{Costs}$$

Management costs:

Fuel	**55%**
Crew	30%
Maintenance	10%
Other	5%

- ✓ European Commission restrictions related to the actual overfishing;
- ✓ impossible to fish more;
- ✓ fishermen do not have influences on the market prices;

A possible solution is to reduce running costs by reducing fuel consumption

Definition of Energy Audit

Regulatory references

- ✓ *Council Regulation (EC) Nr. **2371/2002**, Art. 33: "Conservation and sustainable exploitation of fisheries";*
- ✓ *Council Regulation (EC) Nr. **744/2008** del 24/07/2008: "A Community contribution should also be provided for collective actions aimed at delivering expertise to vessel owners in relation to **energy audits** for vessels".*

Energy audit is a systematic approach to evaluate energy consumption in fisheries.

Objectives

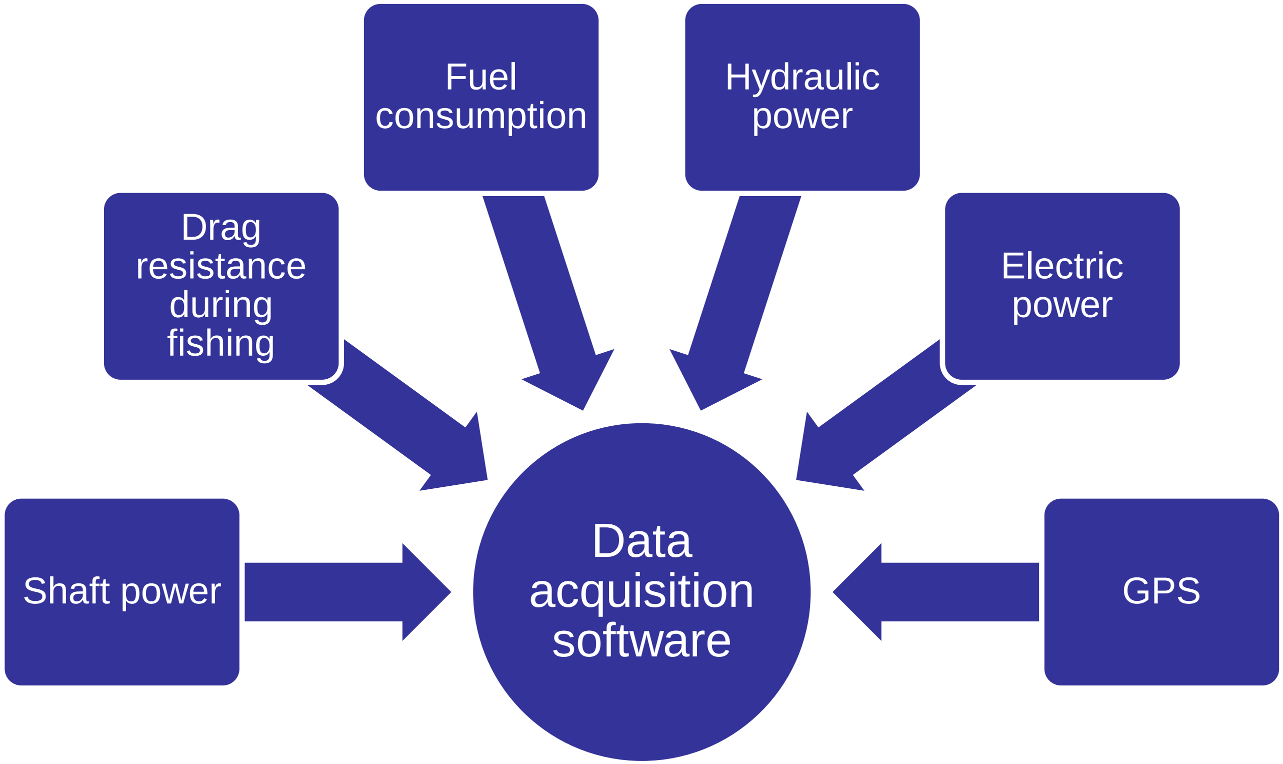
- to define the energetic profile of the fishing vessel trough energy indicators;
- to identify technological improvements;
- to evaluate technical and economical benefits of improvements.

1. Preliminary investigation and inspection of fishing vessel;
2. installation of the instrumentations on board of fishing vessel;
3. sea trials during commercial cruises;
4. data post-processing;
5. evaluation of energy performance indicators;
6. evaluation of energy profiles obtained.

Measurement system: instrumentation installed

Instrumentation	Parameter
Fuel flow meters	Fuel consumption
Torque meter and shaft RPM counter	Delivered power
Oil flow and pressure meter	Hydraulic power
Ammeter claws	Electric power
Strain gauges	Gear drag
GPS	Position, course, speed
Gear monitoring system	Trawl geometry

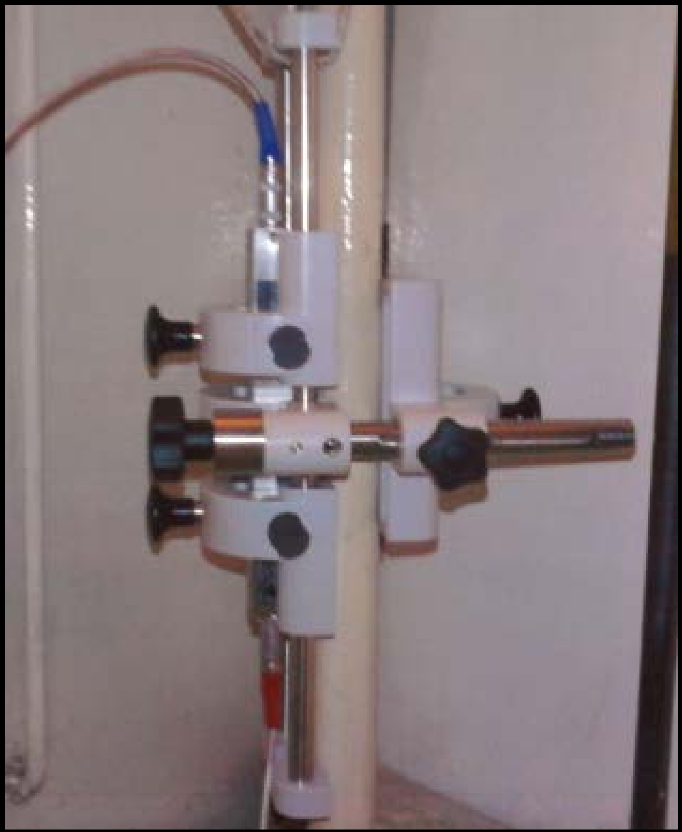
Measurement system: data acquisition software

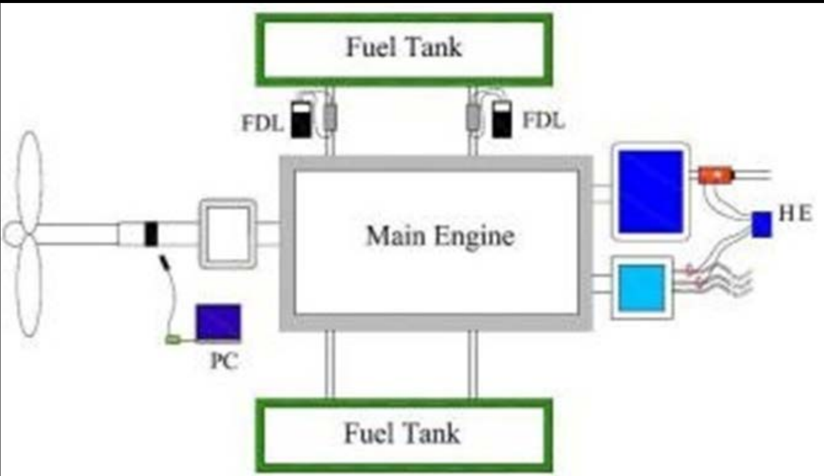


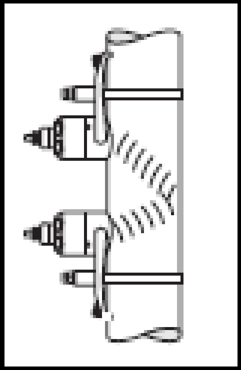
Data acquisition system conceived at CNR–ISMAR

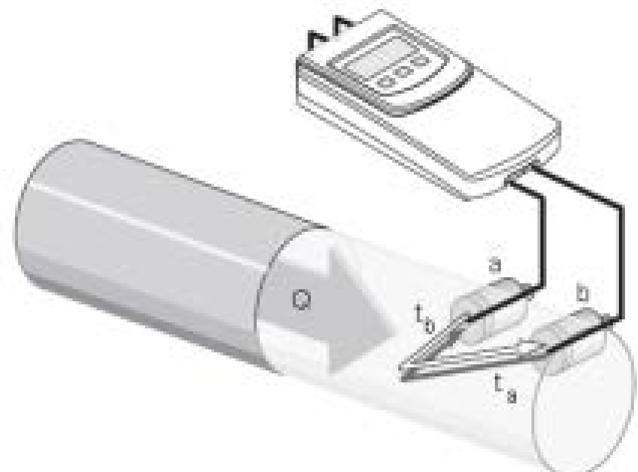
- Post-processing and data synchronization;
- Control of the correct functioning of the acquisition;
- Data recording rate of 5 seconds.

Measurement system: acoustic flow meters

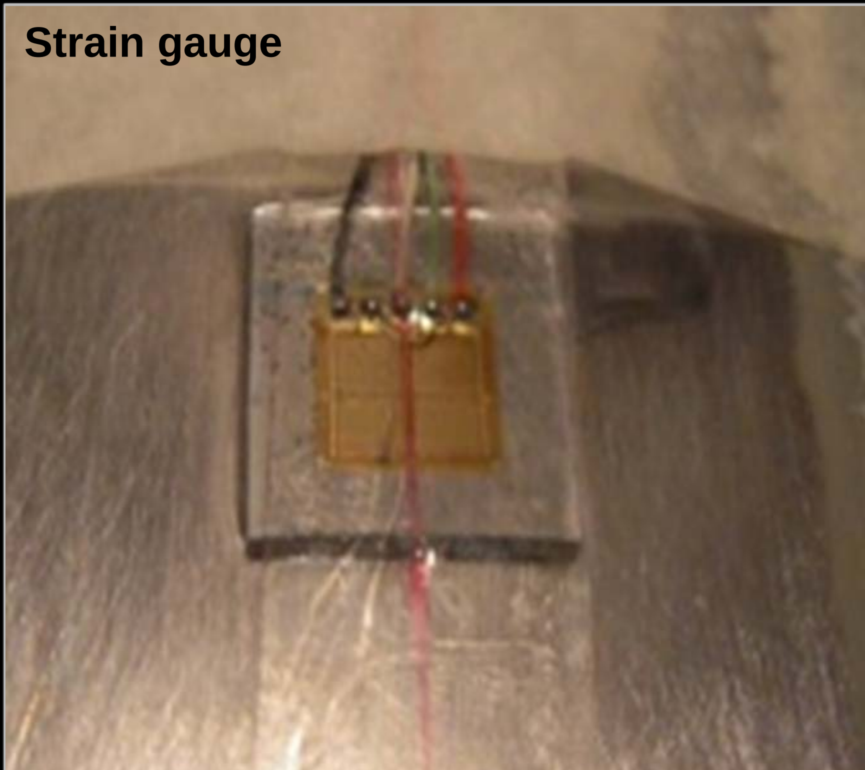






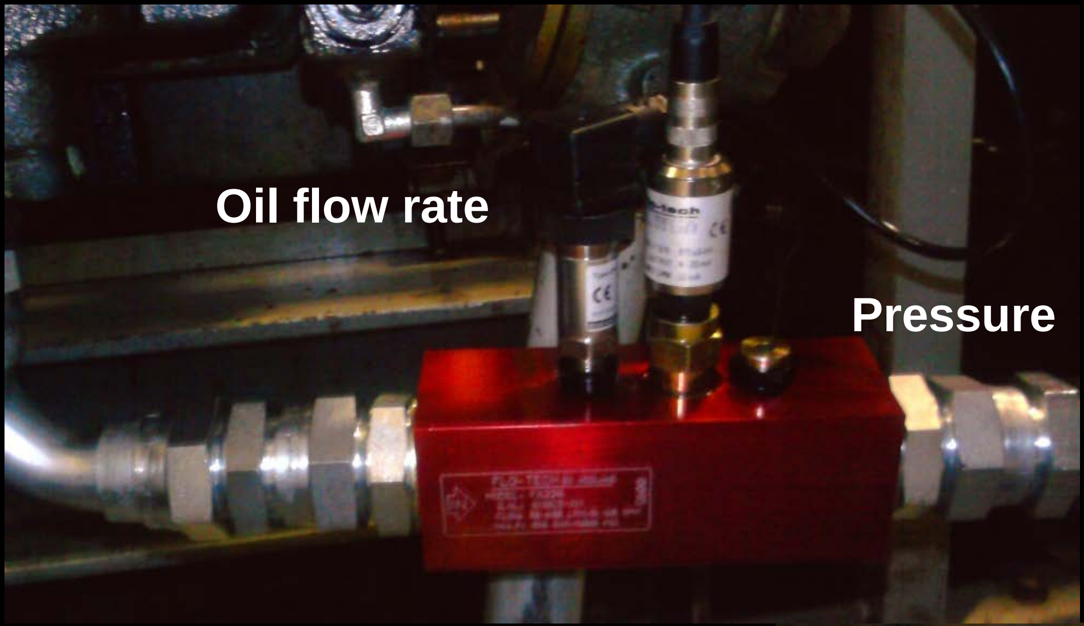


Measurement system: torque meter



Measurement system: torque meter

Measurement system: hydraulic and electric power meter

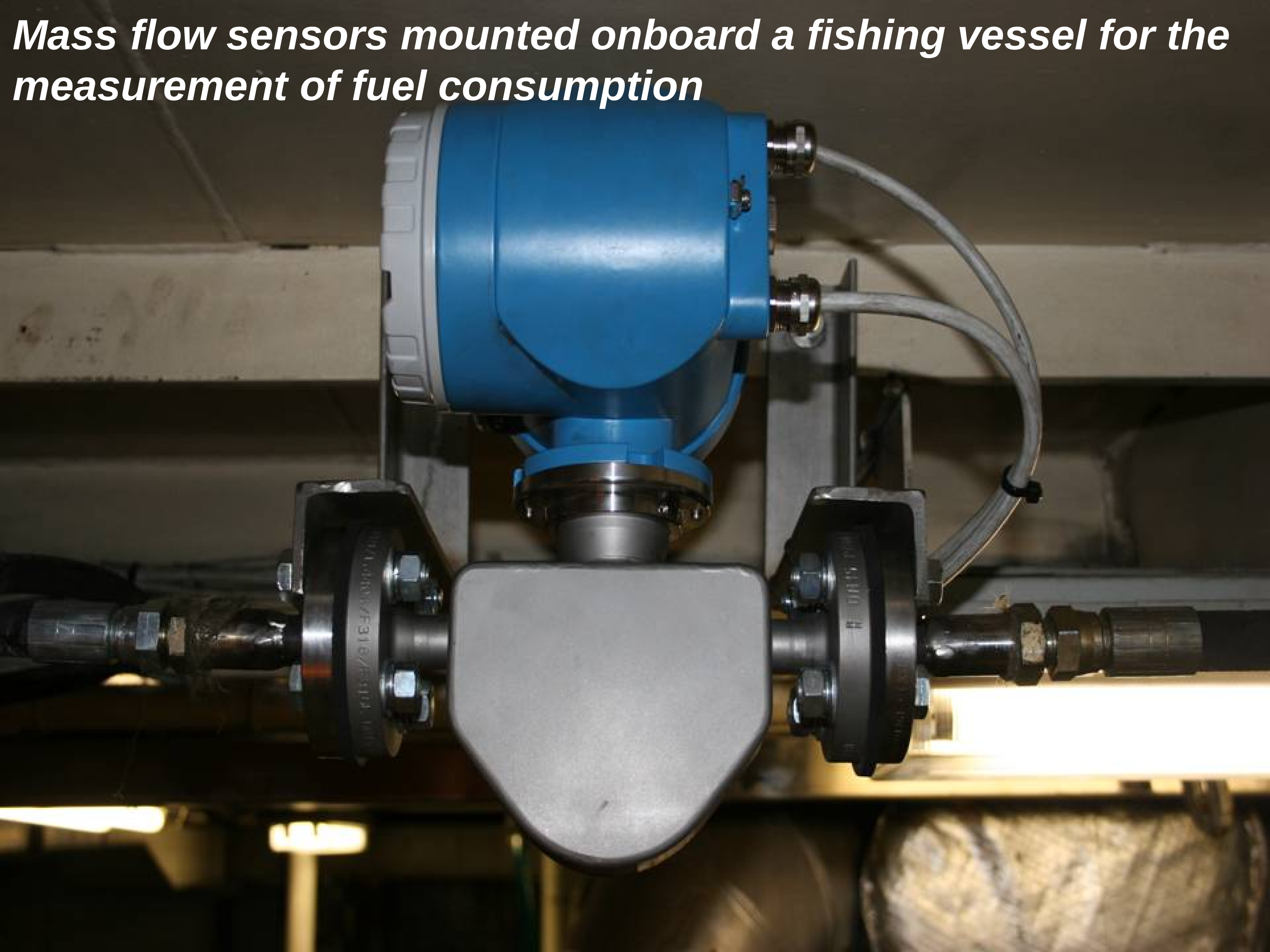


Flow meter and pressure: hydraulic power for deck machinery

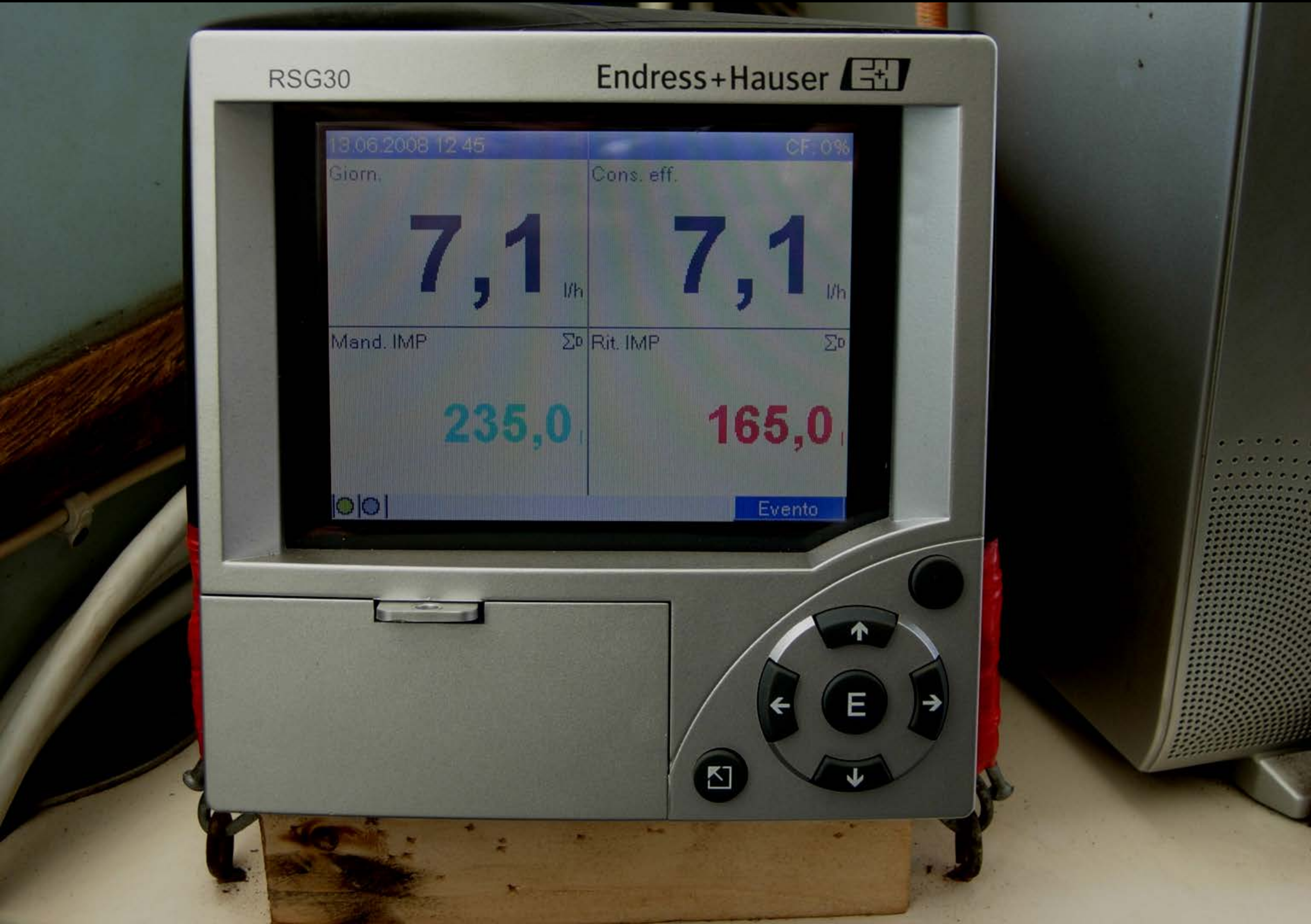
Ammeter claws: electric power used onboard

Measurement system: gear drag sensors

Mass flow sensors mounted onboard a fishing vessel for the measurement of fuel consumption



Multi channel recorder: visualization of the fuel consumption



GPS data logger for the GPS data collection

Main characteristics of the vessels monitored

	L_{OA} [m]	L_{PP} [m]	B [m]	GRT [GT]	P_B [kW]	D [m]
OTB1	21.5	17.0	5.7	82	478	1.78
PTM1	28.6	21.2	6.9	99	940	2.18
OTB2	22.8	19.6	6.2	91	574	1.80
PTM2	29.0	24.3	6.9	138	940	2.20
OTB3	21.5	17.0	5.7	82	478	1.78
PTM3	26.5	21.5	6.8	96	870	2.20
OTB4	22.8	19.6	6.2	91	574	1.80
PTM4	25.5	20.1	6.6	132	772	2.00

OTB, PTM *bottom otter trawler; midwater pair trawler*
L_{OA} *length overall*
L_{PP} *length between perpendiculars*
B *beam*
GRT *international gross tonnage*
P_B *brake power*
D *propeller diameter*

Energy performances indicators

Energy Consumption Indicator (ECI)

$$ECI = \frac{E_T}{P_D \cdot v}$$

$$[\mathbf{ECI}] = \frac{[\mathbf{kJ}]}{[\mathbf{kW}] \cdot [\mathbf{kn}]}$$

Fuel Consumption Indicator (FCI)

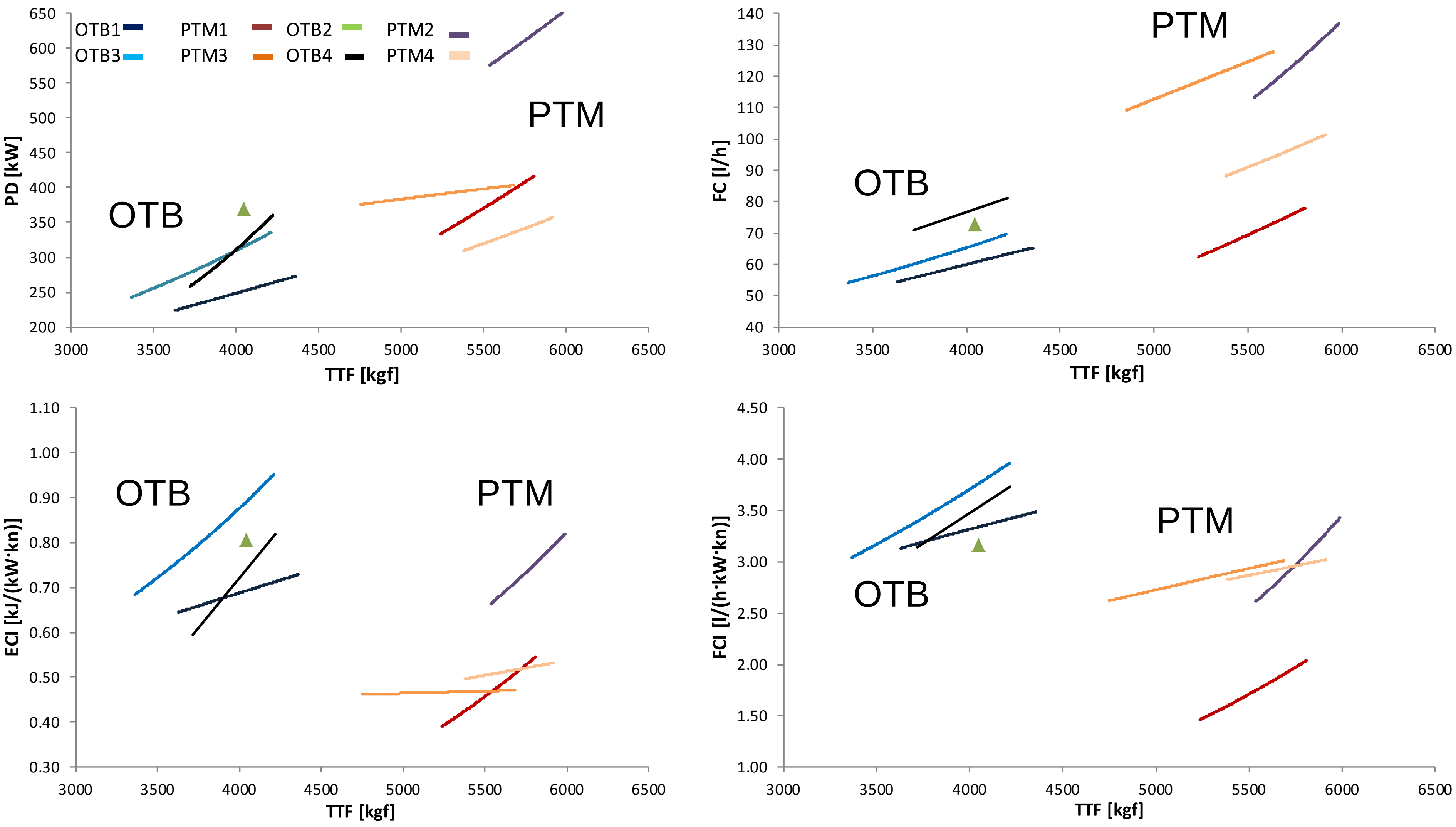
$$FCI = \frac{F_C}{P_D \cdot v}$$

$$[\mathbf{FCI}] = \frac{[l/h]}{[\mathbf{kW}] \cdot [\mathbf{kn}]}$$

By fishing phase (e.g. sailing, trawling)

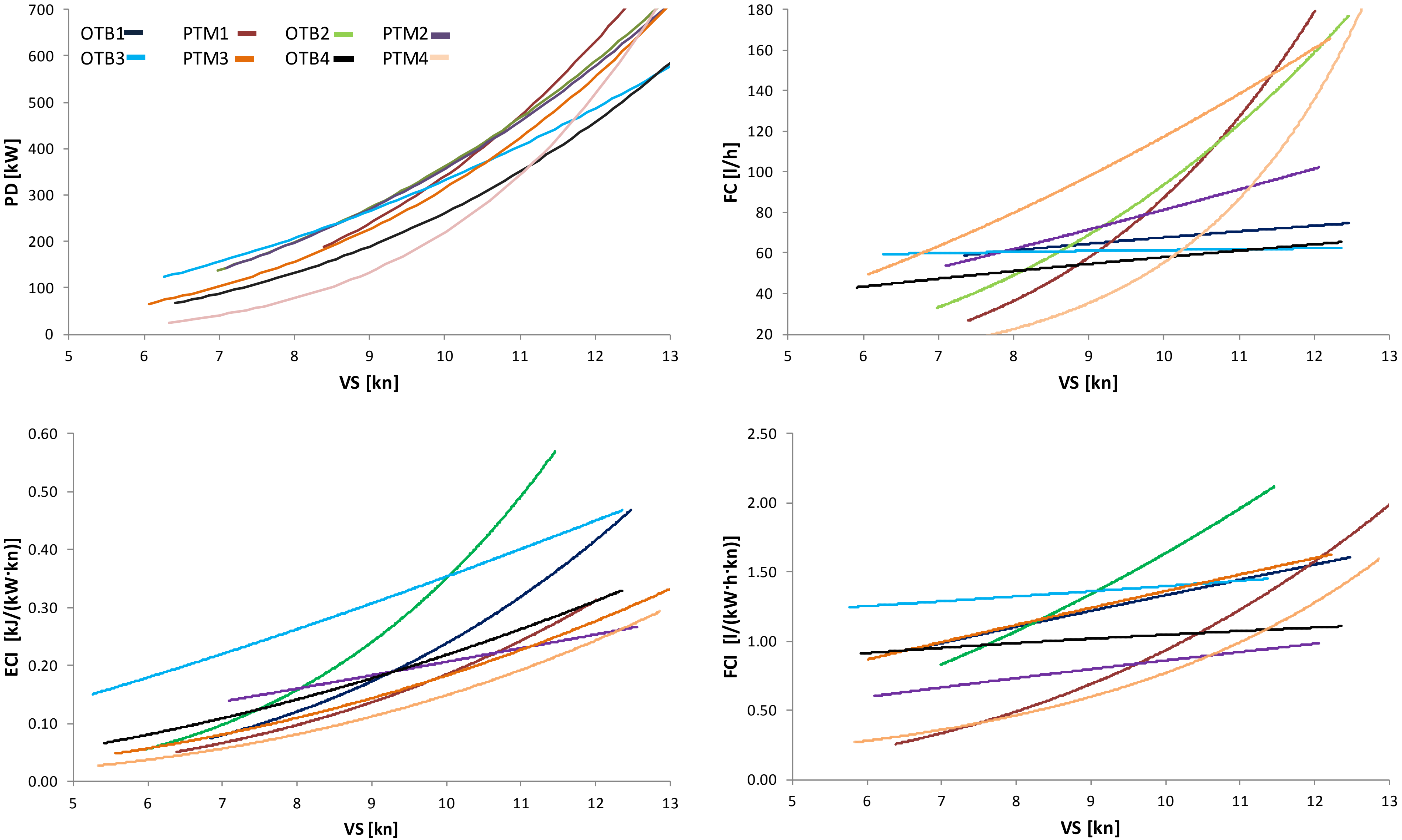
E_T *Total energy*
F_C *Total fuel consumption*
P_D *Power delivered*
v *Vessel speed*

Results: trawling phase



PD ***power delivered*****; FC** ***fuel consumption*****; TTF** ***total towing force*****; ECI** ***energy consumption index*****; FCI** ***fuel consumption index*****; OTB** ***bottom otter trawler*****; PTM** ***mid-water pair trawler*****.**

Results: sailing phase



PD *power delivered*; FC *fuel consumption*; VS *vessel speed*; ECI *energy consumption index*; FCI *fuel consumption index*; OTB *bottom otter trawler*; PTM *mid-water pair trawler*.

Results: ranking for vessels monitored

ECI of trawling and sailing conditions have been pooled.

PD *power delivered*; FC *fuel consumption*; ECI *energy consumption index*; FCI *fuel consumption index*; OTB *bottom otter trawler*; PTM *mid-water pair trawler*.

	Fishing				Sailing			
	ECI	FCI	ECI/FCI	Rank	ECI	FCI	ECI/FCI	Rank
OTB1	0.69	3.32	0.21	6	0.22	1.45	0.15	6
PTM1	0.47	1.76	0.27	1	0.20	1.00	0.20	3
OTB2	0.81	3.16	0.25	2	0.32	1.56	0.21	4
PTM2	0.74	3.01	0.25	3	0.21	0.88	0.24	2
OTB3	0.83	3.56	0.23	4	0.28	1.36	0.21	1
PTM3	0.47	2.84	0.16	8	0.16	1.32	0.12	8
OTB4	0.71	3.36	0.21	5	0.15	1.01	0.15	5
PTM4	0.52	2.93	0.18	7	0.15	0.87	0.17	7

Main conclusions

- Monitored fishing vessels were not so efficient because of outdated technology. Restrictions on new constructions impose modernizations;
- Energy saving is the key to maintain acceptable and sustainable profitability in fisheries;
- An energy saving strategy is necessary in order to find potential areas of improvements;
- Gains in propulsive efficiency during free navigation might be attained using a controllable pitch instead of a fixed pitch propeller, which can permit an optimum combination of pitch ratio and propeller revolutions for each operating condition;
- In the steaming conditions fuel saving can be obtained by reducing vessel speed;
- Other energy users (hydraulic and electric users) did not show to have noticeably influenced energy consumption, compared to the propulsion system.

Potential engineering topics

- First adaptation: Development of fuel saving bottom trawl

- Second adaptation: Improvement of otterboard design on OTB

First adaptation: Development of fuel saving bottom trawl

Traditional trawl

Commonly used in the Italian commercial fishery

Experimental trawl

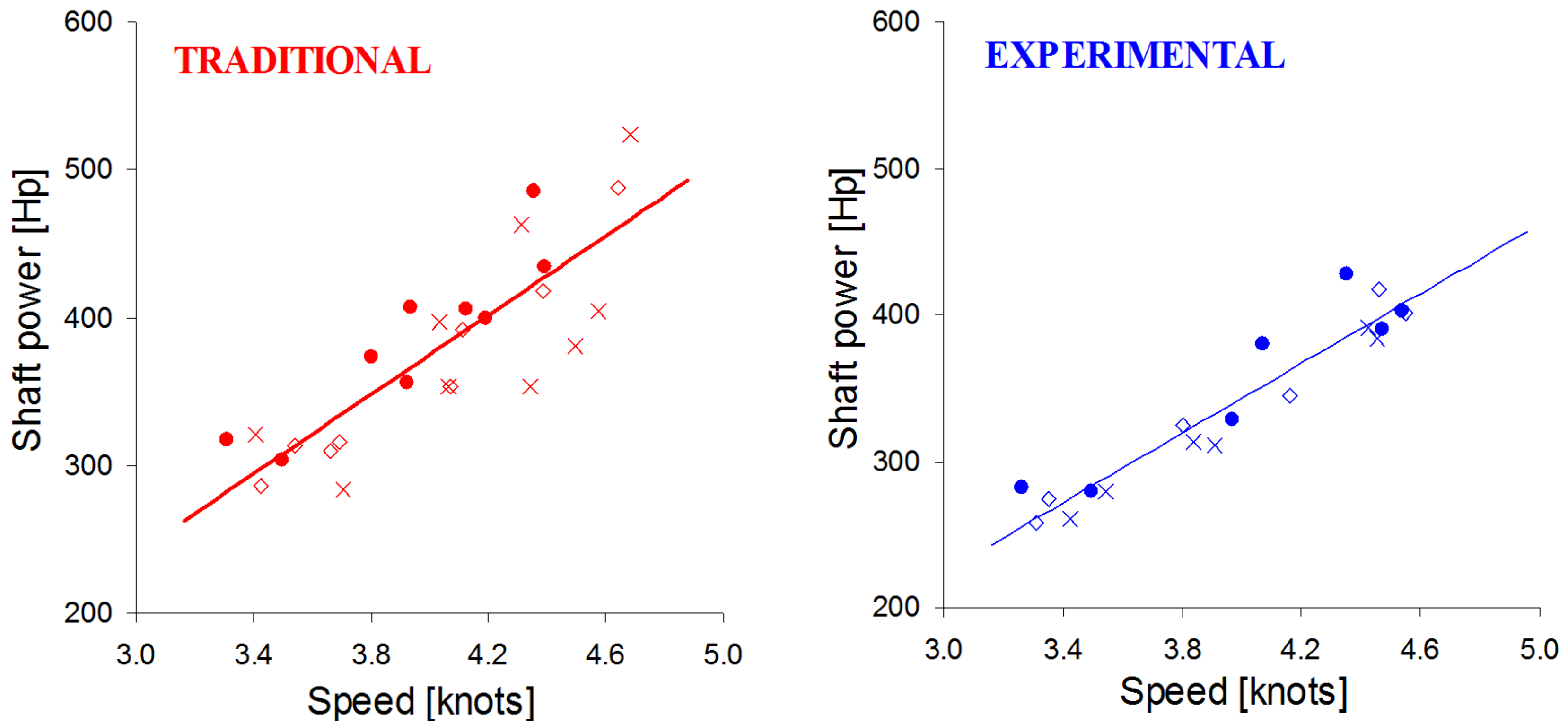
Knotted *Rubitech* netting sections in the wings

Wing is a new design → larger vertical opening

Reduction of the wing netting area

Meshes number redistribution

First adaptation: Development of fuel saving bottom trawl



First adaptation: Development of fuel saving bottom trawl

Economical analysis

Speed knots	Standard Trawl Power HP	Standard Trawl Fuel consumption [l/hour]	Experimental Trawl Power HP	Experimental Trawl Fuel consumption [l/hour]	Fuel saving [l/hour]
3.25	274	51.8	254	48.8	2.9
3.50	308	56.6	283	53.1	3.5
3.75	341	61.4	313	57.4	4.0
4.00	375	66.2	343	61.6	4.6
4.25	408	71.0	373	65.9	5.1

Profile for a vessel of Ancona (Italy)

Days at sea	180
Days fishing	180
Hours fishing per day	16
Hours fishing per year	2880
Fuel cost (Euro/l)	0.40
Towing speed [kn]	4.00

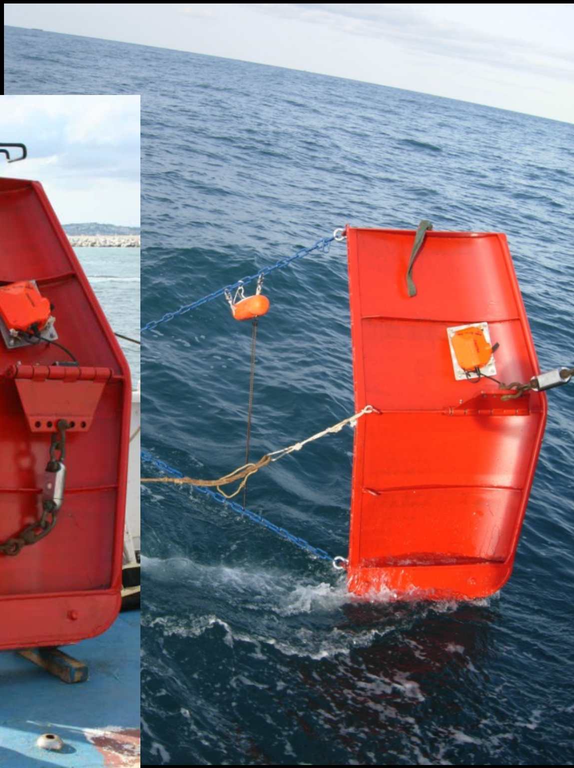
Gear Investments (Euro)

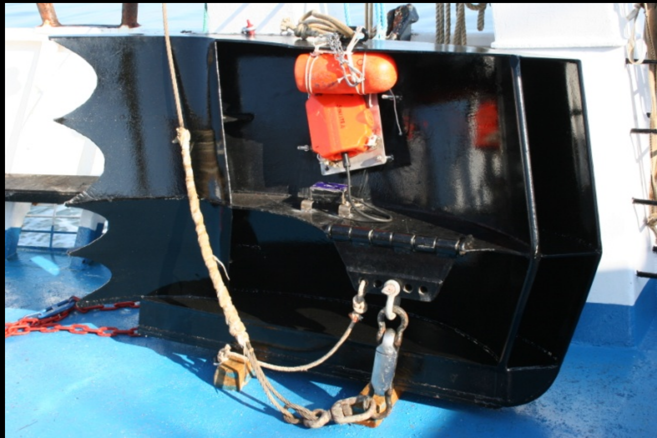
Traditional trawl	1675
Experimental trawl	2725
Extra investment	*1050*

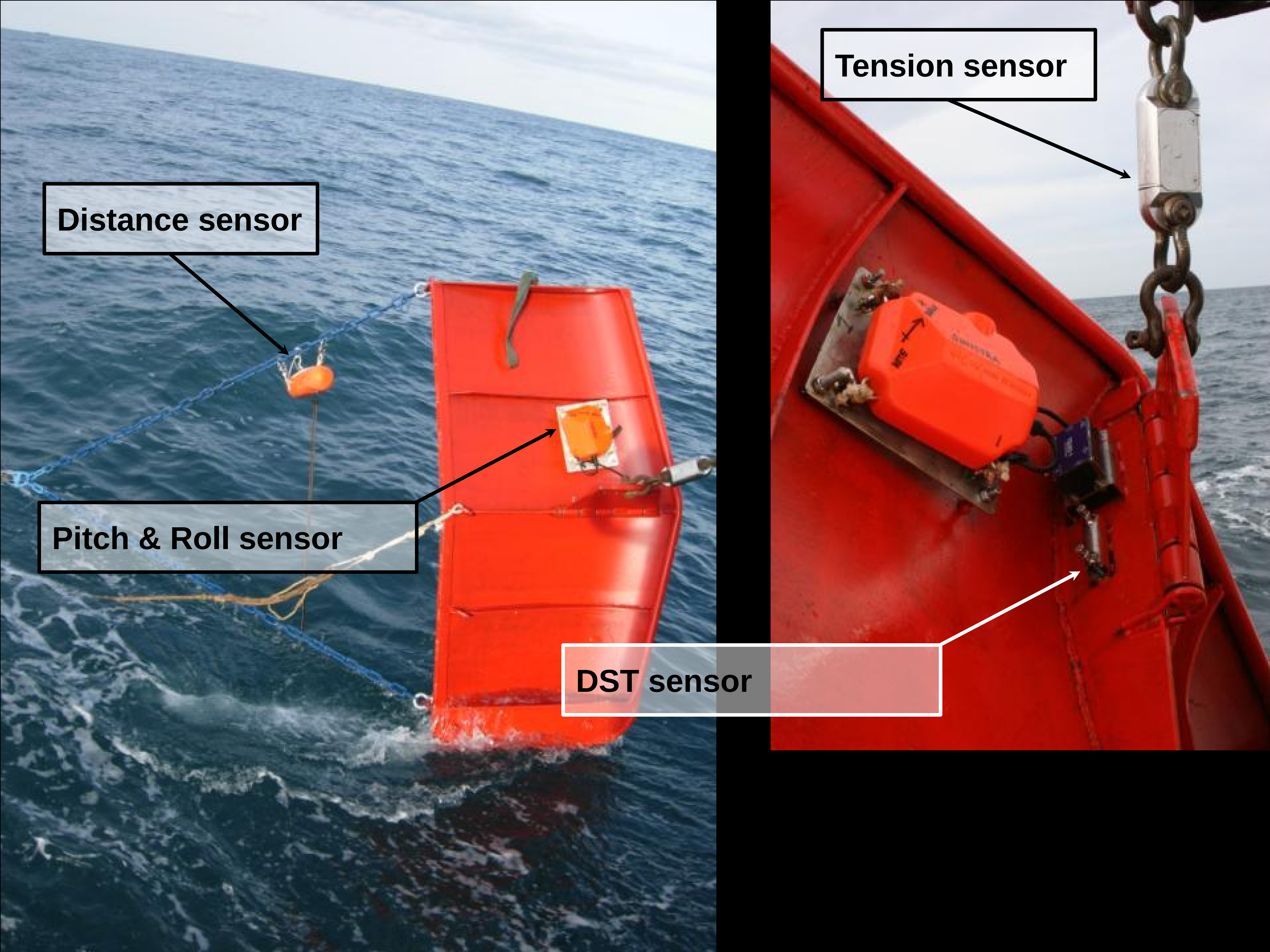
Fuel cost per year (Euro)

Traditional trawl	76262
Experimental trawl	70963
Comparison	*5299*

Second adaptation: Improvement of otterboard design in OTB

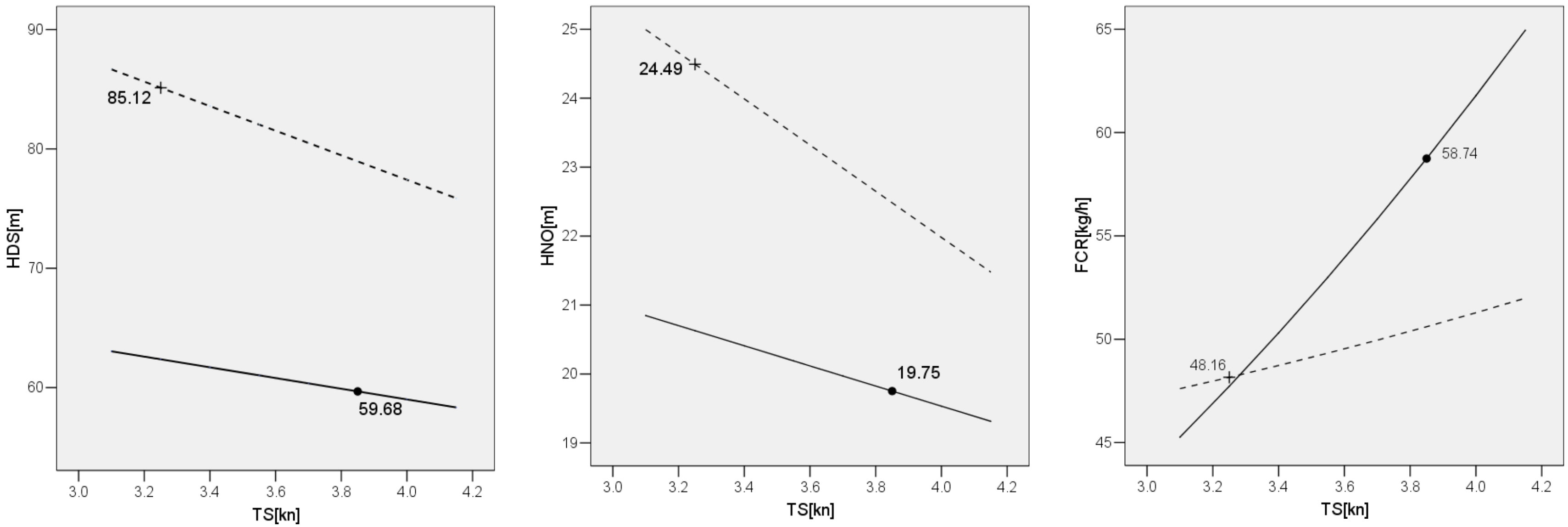






Distance sensor
Pitch & Roll sensor
Tension sensor
DST sensor

Comparison between the traditional VEE (VEE) and the Thyboron type VF15 (VF15) otterboard



Test comparison between the traditional VEE otterboard (circle points and continuous line) and the Thyboron type VF15 otterboard (cross points and dotted lines). HDS[m]: horizontal door spread; HNO[m]: horizontal net opening; FCR[kg/h]: fuel consumption rate; TS[kn]: towing speed. Values at TS of 3.25 and 3.85 kn were reported for the VF15 and the VEE otterboard respectively.

Comparison between the traditional VEE (VEE) and the Thyboron type VF15 (VF15) otterboard

Parameter		VEE	VF15	Diff.	Diff%
TS	[kn]	3.85	3.25	-0.60	-15.6%
HDS	[m]	61.13	86.57	25.45	41.6%
HNO	[m]	19.88	24.61	4.74	23.8%
VNO	[m]	1.67	1.70	0.03	1.6%
FCR	[kg/h]	58.74	48.16	-10.59	-18.0%
AEH	[1000m^2]	141.72	148.15	6.43	4.5%
FCH	[kg/1000m^2]	0.41	0.33	-0.09	-21.6%

Mean value of horizontal door spread (HDS); horizontal net opening (HNO); fuel consumption rate (FCR); vertical net opening (VNO); towing speed (TS); area explored in 1-hour-haul (AEH); fuel consumption per area explored (FCH).

Catch comparison between the traditional VEE (VEE) and the Thyboron type VF15 (VF15) otterboard

Door	COM [kg/h]	DEB [kg/h]	DIS [kg/h]	FC [kg/h]	COM [kg fish / kg fuel]
VEE	12.98	3.15	25.98	58.74	0.22
VF15	12.33	3.42	16.05	48.16	0.26
Diff.	-0.65	0.27	-9.93	-10.59	0.04
Sig. p	*0.883*	*0.916*	*0.303*		

COM: total commercial catch per hour;
DEB: total debris per hour;
DIS: total discards catch per hour.

Economic analysis

	Day							Total	
Fishing operation	**Mon**	**Tue**	**Wed**	**Thu**	**Fri**	**Sat**	**Sun**	**Weekly**	**Yearly**
Steaming to and from fishing grounds	2	2	1	1	0	0	0	**6**	**282**
Shooting and hauling gears	4	4	4	2	0	0	0	**14**	**658**
Fishing	15	15	16	7	0	0	0	**53**	**2491**
Searching	0	0	0	0	0	0	0	**0**	**0**
Time in harbour during Working weeks	3	3	3	14	24	24	24	**95**	**4465**
Total	24	24	24	24	24	24	24	**168**	**7896**

Profile for a vessel of Ancona (Italy)	
Working hours/week	168
Closed weeks per year	5
Trawling hours/year	2491
Fuel cost (EUR/l)	0.60

Door investement	EUR
VEE	3,500
VF15	7,000
Extra Investement	3,500
Fuel cost per year	
VEE	70,238
VF15	57,580
Comparison	*12,658*

Conclusions

The VF15 otterboard produced horizontal openings much greater than those obtained with the VEE otterboard, but with less fuel demands.

The greater horizontal openings obtained with the VF15 have surely increased the net drag, therefore improvements of around 18% in the fuel saving, due to the change of the door, might have been underestimated.

Monitoring the height of the otterboards above the bottom has required appropriate acoustic instruments which have been used to adjust the door height by altering the towing speed and the trawl warp length.

The investment for two VF15 otterboards, including all the rigging components (weight, backstrops chains, etc.) is estimated at around 7.0 KEUR. A lower investment of 3.5 KEUR is required for the VEE otterboards.

Assuming that the catching power is equal for the two doors, the payback time for the new door investment will be less than 4 months.