Effects of current speed and turbidity on stationary light-trap catches of larval and juvenile fishes

David C. Lindquist

Richard F. Shaw

Coastal Fisheries Institute
School of the Coast and Environment
Louisiana State University
Baton Rouge, Louisiana 70803
E-mail address (for D. C. Lindquist): dlindq1@lsu.edu

Light traps are one of a number of different gears used to sample pelagic larval and juvenile fishes. In contrast to conventional towed nets, light traps primarily collect larger size classes, including settlement-size larvae (Choat et al., 1993; Hickford and Schiel, 1999; Hernandez and Shaw, 2003), and, therefore, have become important tools for discerning recruitment dynamics (Sponaugle and Cowen, 1996; Wilson, 2001). The relative ease with which multiple synoptic light trap samples can be taken means that larval distribution patterns can be mapped with greater spatial resolution (Doherty, 1987). Light traps are also useful for sampling shallow or structurally complex habitats where towed nets are ineffective or prohibited (Gregory and Powles, 1985; Brogan, 1994; Hernandez and Shaw, 2003).

As with any sampling gear, there are concerns about light trap sampling biases and efficiency. Light traps are taxon-selective because they target fishes that are photopositive and able to swim to and enter the trap (Thorrold, 1992; Choat et al. 1993; Hernandez and Shaw, 2003), and size-selective because both phototactic behavior and swimming abilities change during ontogeny (Stearns et al., 1994; Fisher et al., 2000). Unlike conventional towed nets, it is difficult, if not impossible, to quantify the volume of water sampled by light traps. This is largely due to external, environmental factors such as lunar phases, current speed or water clarity, which may have a large impact on catch rates (Doherty, 1987; Meekan et al, 2000).

Few studies have attempted to address the effects of environmental factors on light trap performance. Catches have been found to be lower during full moons as compared to new moons, either because of the greater ambient illumination interfering with light trap efficiency (Gregory and Powles, 1985; Hickford and Schiel, 1999) or because of higher abundances of presettlement fish during the darker lunar phases (Johannes, 1978; Robertson et al., 1988). Thorrold (1992) showed that catches were greater for light traps drifting with the current as compared to traps anchored in the current flow. Anderson et al. (2002) found that anchored light traps were less efficient at a high-current sampling site as compared with a low-current sampling site. The latter two studies, however, did not provide any information on catch rates with variation in current speed. The purpose of this study was to assess the relationships between catch rates from stationary (anchored or tethered) light traps at offshore petroleum platforms and concurrent measurements of current speed and turbidity.

Materials and methods

Study sites

Larval and juvenile fishes were collected at five oil and gas platforms (platforms) in the north-central Gulf of Mexico. These platforms included: Mobil's Green Canyon 18 (27°56′37″N, 91°0′45″W; sampled from July 1995–June 1996); Mobil's Grand Isle 94B (28°30′57″N, 90°07′23″W; April–August 1996); Exxon's South Timbalier 54G (28°50′01″N, 90°25′00″W; April–September 1997); Santa Fe-Snyder's Main Pass 259A (29°19′32″N, 88°01′12″W; May–September 1999); and Murphy Oil's Viosca Knoll 203 (29°46′53″N, 88°19′59″W; May–October 2000). All platforms had similar underwater structural complexity, and had well-developed biofouling communities when sampled.

Sampling procedures

Sampling procedures have been described in detail elsewhere (Hernandez and Shaw, 2003) and will be briefly described here. Fish collections were made by using a modified quatrefoil light trap with a Brinkman Starfire II halogen light (250,000 candlepower) powered through an umbilical by a 12-volt marine battery. Light traps were deployed in surface waters within the platform structure along a stainless-steel guidewire (within-platform light trap), and tethered and floated in surface waters to a distance of 20 m from the down-current side of the platform (off-platform light trap). Light traps were deployed with their lights off, fished with lights on for 10–15 min, and retrieved with lights off.

Sampling was undertaken generally twice monthly coincident with new and full moon phases. During each trip, light traps were fished during four to six sets per night, starting at least one hour after sunset and ending at least one hour before sunrise, over two to three consecutive nights. Each sample set consisted of a within-platform light trap collec-

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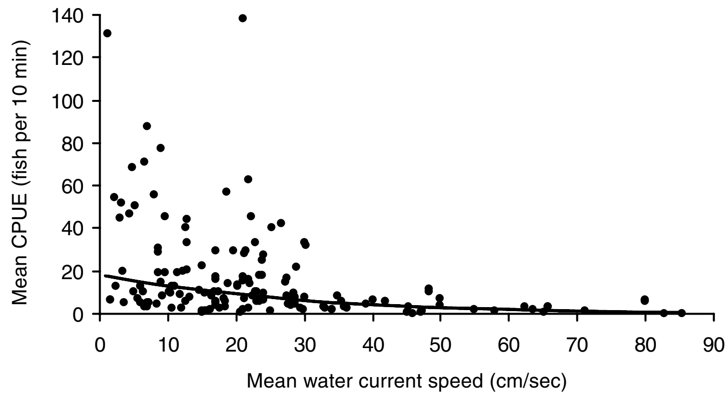

Figure 1

Mean total CPUE per sampling set (from within- and off-platform light traps) in relation to the mean current speed per sampling set. Data from all platforms were combined. Line calculated from the regression equation: $\log_{10}(y+1) = -0.013x + 1.302$, $r^2=0.23$.

tion and an off-platform light trap collection in random order. During sampling, turbidity (Nephelometric turbidity unit: NTU) was measured every 5 sec by using a Hydrolab DataSonde3 suspended in surface waters within the platform structure. Current speed and direction were measured every 10 min with an InterOcean S4 Current Meter suspended 1–2 m below the surface on the up-current side of the platform. Because the platform structure undoubtedly reduced current speeds (Forristall, 1996), current data taken from this location should be considered as relative estimates for the light trap collections.

Samples were preserved in 10% buffered formalin and transferred to ethanol within 12 hours. Fish were enumerated and identified to the lowest possible taxonomic level. Preflexion larvae were measured to notochord length, and postflexion and juvenile fish were measured to standard length. Data from light trap catches were standardized to a catch per unit of effort (CPUE) of number of fish per 10 minutes.

Data analyses

We assumed that there were no inter-location differences in the relationship between light trap CPUE and current speed or turbidity; therefore, data from all platforms for the months May to September were combined. The relationship between total light trap CPUE and current speed or turbidity was analyzed by using regression analysis. Current speed and turbidity were analyzed separately, rather than in a multiple regression analysis, because there was a limited number of sampling sets where we had data for light trap CPUE, current speed and turbidity together ($n=60$, or 31% and 37% of the available turbidity and current data, respectively). There were no significant differences in the regression coefficients of CPUE vs. current speed or turbidity between within- and off-platform light traps ($P>0.15$); therefore, the CPUEs from both light traps were averaged for each sampling set. Mean total CPUEs were log-transformed ($\log_{10}(y+1)$) and analyzed with the mean current speed or turbidity from each respective sampling set. Mean CPUEs were also calculated for the dominant families collected; however, regression analyses could not be performed because variances remained heterogeneous after transformation.

To investigate how fish size (i.e., locomotive ability) influenced light trap catches with increasing current speed, length-frequency distributions of all fishes collected at different current speed intervals (0–9, 10–19, 20–29, 30–39, 40–49 and >49 cm/sec) were compared by using Kolmogorov-Smirnov tests ($\alpha=0.05$). The length-frequency figures were subdivided by three ecological groupings: clupeiforms (Clupeidae and Engraulidae); demersal taxa (predominantly Synodontidae and Blenniidae); and scombrids and carangids, to further assess whether any changes in the size of fish collected over the current intervals were due to a particular group. All statistics were performed with SAS version 6.12 (SAS Institute, Cary, NC).

Results

Current speed

Mean total CPUEs generally decreased with increasing current speed (Fig. 1). At current speeds ≤30 cm/sec, light trap catches were highly variable (CPUEs ranged from 0 to 138 fish per 10 min); however, CPUEs >20 fish per 10 min occurred only at these lower speeds. Although there were fewer samples at speeds >30 cm/sec,

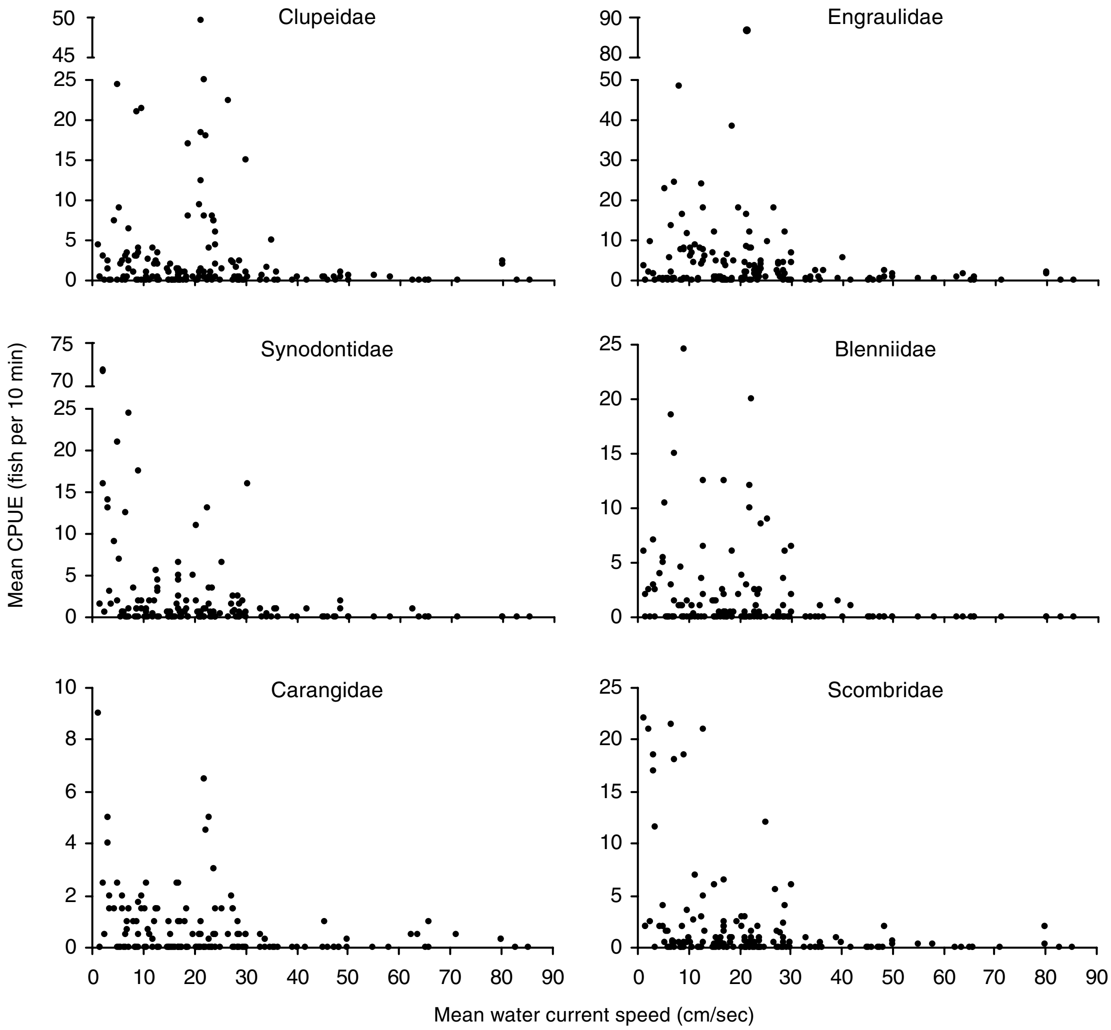

Figure 2

Mean CPUE per sampling set (from within- and off-platform light traps) in relation to the mean current speed per sampling set for each of the dominant families collected. Data from all platforms were combined. Note changes in the scale of the y-axis.

CPUEs were mostly <5 fish per 10 min at these speeds. There was a significant linear relationship between log-transformed mean total CPUE data and mean current speed ($\log_{10}(y+1) = -0.013x + 1.302$, $r^2=0.23$; $F=49.61$, $P<0.0001$).

Each of the dominant families collected by light traps showed a similar pattern of highest mean CPUEs at current speeds <30 cm/sec and relatively low mean CPUEs at higher current speeds (Fig. 2). Clupeidae, Engraulidae, and Blenniidae showed a slight trend of highest CPUEs at intermediate current speeds (10–30 cm/sec), whereas the other families generally had highest CPUEs at the lowest speeds (<10 cm/sec). Synodontidae and Blenniidae were rarely collected at current speeds >40 cm/sec, and small numbers of Clupeidae, Engraulidae, Carangidae, and Scombridae were collected at speeds up to 80 cm/sec.

As current speeds increased, light trap collections became limited to smaller size classes of fish (Fig. 3). For the first three current intervals, i.e., 0–9, 10–19, and 20–29 cm/sec, a broad range of sizes were collected and the distributions had median lengths of 15–19 mm. However, beginning at the fourth current interval, 30–39 cm/sec, the size distributions shifted toward an increasingly greater proportion of the catch <10 mm in length. This trend was most pronounced at the two highest current intervals, 40–49 and >49 cm/sec, both of which had distributions with median lengths of 5 mm. The size distributions from the two highest current intervals were the only distributions that were not

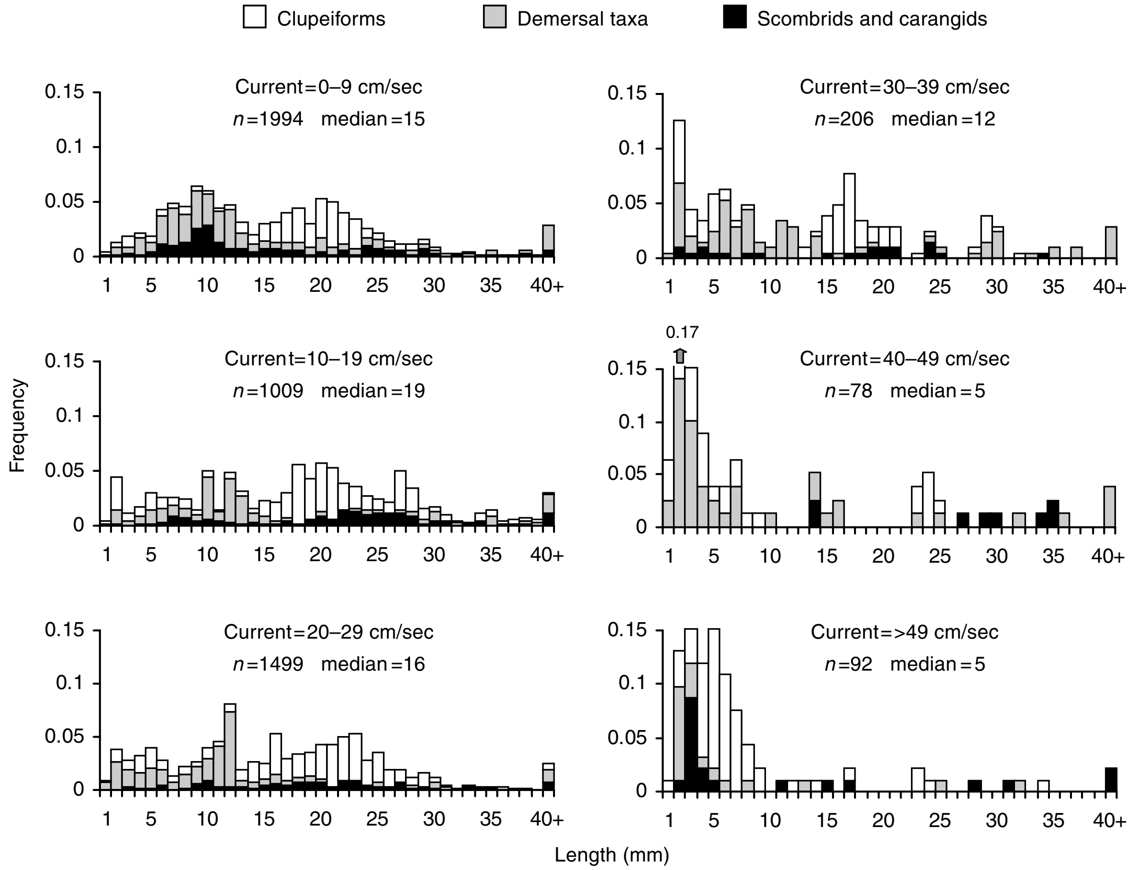

Figure 3

Size distributions of fishes collected by light traps from all platforms at different current speed intervals. The total number of fish collected (n) and the median length (mm) over each interval are included. Size distributions are further subdivided by three general ecological groupings: clupeiforms (Clupeidae and Engraulidae), demersal taxa (i.e., more substrate-oriented fishes such as synodontids and blenniids), and scombrids and carangids.

significantly different from each other (P=0.11). The decrease in the frequency of fishes larger than 10 mm at the higher current intervals was not limited to any particular ecological grouping, i.e., pelagic fishes such as clupeiforms, scombrids, and carangids were as rare as demersal taxa.

Turbidity

Mean total CPUEs generally decreased with increasing turbidity (Fig. 4). Highest catches (CPUEs >50 fish per 10 min) predominantly occurred at turbidities below 1.0 NTU, whereas at higher turbidities catches were generally lower. There was a significant linear relationship between log-transformed mean total CPUE data and mean turbidity ($\log_{10}(y+1)=-0.25x + 1.48$, r^2=0.08; F=11.86, P=0.0007).

The majority of the dominant families showed a similar pattern of highest mean CPUEs at turbidities <1.0 NTU, and relatively low mean CPUEs at higher turbidities (Fig. 5). Clupeidae, however, showed a pattern of high CPUEs at turbidities <0.5 NTU and between 1.0 and 2.0 NTU.

Discussion

Light trap catches of larval and juvenile fishes appeared to be negatively affected by increasing current speeds at platforms. This was expected because stronger currents may interfere with a fish's ability to swim to and enter a light trap (Doherty, 1987; Thorrold, 1992; Anderson et al., 2002). Doherty (1987) predicted that, for stationary (anchored or tethered) light traps, catches should increase initially with current speed as more water is sampled, but then decrease as current speed interferes with catchability. Although mean total CPUEs clearly decreased with increasing current speed, they

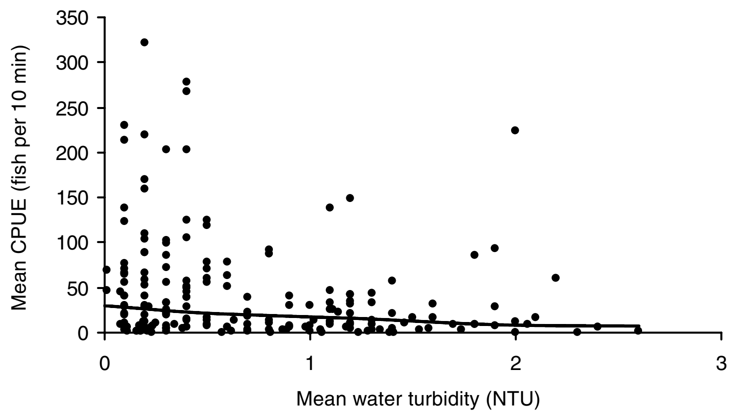

Figure 4

Mean total CPUE per sampling set (from within- and off-platform light traps) in relation to the mean turbidity per sampling set. Data from all platforms were combined. The line was calculated from the regression equation: $\log_{10}(y+1) = -0.25x + 1.48$, r^2=0.08. Included in the analysis, but not shown in the plot, were three points from 583 to 878 CPUE between 0.2 to 0.5 NTU.

did not appear to peak at some intermediate current level. These results, however, represented the total catch of all fishes, and the relationship between current speed and light trap catches may be more taxon specific (Doherty, 1987). When analyzed at the family level, a bell-shaped relationship may have occurred for Clupeidae, Engraulidae, and Blenniidae; however, the pattern was indistinct and there was generally little difference among families.

The lack of any strong differences in the relationship between light trap CPUEs and current speed among the dominant families was unexpected, considering the potential differences in swimming abilities. Because larvae and juveniles of demersal fishes are generally believed to have lower swimming speeds (Blaxter, 1986), it was anticipated that catches of synodontids and blenniids would have been more negatively affected by increasing current speed than relatively stronger-swimming pelagic taxa (e.g., scombrids and carangids). Perhaps larvae of demersal taxa have greater swimming capabilities than previously considered, as has been recently found for certain settlement-stage larval reef fishes (sustained swimming speeds of 20–60 cm/sec; Stobutzki and Bellwood, 1994; Leis and Carson-Ewart, 1997). However, despite possible strong swimming abilities, few larval and juvenile demersal or pelagic fishes were collected at current speeds >40 cm/sec, and of these the majority were preflexion larvae that were undoubtedly passively entrained in the light trap. It is possible that the larvae and juveniles of taxa collected at platforms were unable to maintain the metabolic power required to swim against the stronger currents over extended distances from the light trap (Fisher and Bellwood, 2002).

Currents may have interfered with the functioning of the light traps. Assuming that larval and juvenile fishes were able to swim against the stronger currents, their ingress into the light trap may have been impeded by turbulence created by the current flow around the trap. If turbulence occurred after some critical current speed, then this may explain the lower CPUEs beginning at around 30 cm/sec observed for each of the dominant families.

Higher turbidity also appeared to have a negative effect on light trap catches at platforms. Light trap catch efficiency should be greatly impaired by highly turbid waters because greater light attenuation would reduce the effective sampling radius of the trap. In addition, the phototactic response of larval and juvenile fishes may be lower at lower light intensities (Gehrke, 1994; Stearns et al., 1994). However, it is uncertain whether the relatively small range of turbidities (0.1–2.6 NTU) sampled during this study would result in a significant decrease in light trap catch efficiency, particularly given the intensity of the light source used (250,000 candlepower). The observed patterns may have been a reflection of intrusions of turbid coastal and Mississippi River plume water at the platforms, during which light trap catches comprised large numbers of coastal clupeids and relatively few other taxa (Fig. 5).

Although they were treated separately for the purposes of this study, the effects of current speed and turbidity also may have been interrelated. A positive relationship between turbidity and current speed was found for a limited data set where both variables were available (r^2=0.28, P<0.0001). It is unlikely that this relationship was caused by the resuspension of benthic sediments, given the water depth at the platforms (20–230 m), but

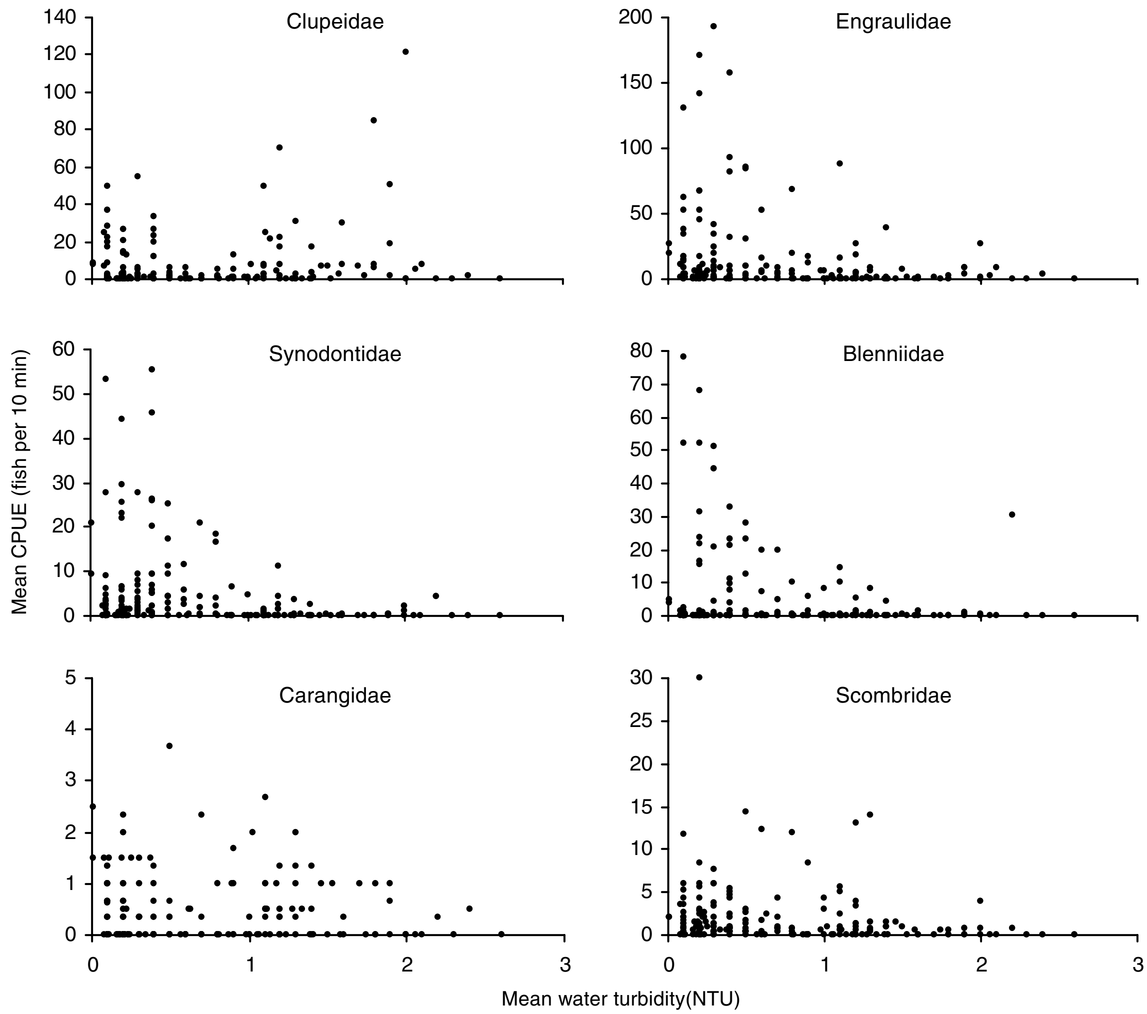

Figure 5

Mean CPUE per sampling set (from within- and off-platform light traps) in relation to the mean turbidity per sampling set for each of the dominant families collected. Data from all platforms were combined. Note changes in the scale of the *y*-axis. Not shown in the Engraulidae plot were three points from 551 to 606 CPUE between 0.2 and 0.5 NTU.

particles may have been flushed from the platforms and their associated biofouling communities by currents. In a comparison of light trap catches between adjacent beach and rocky shore habitats, Hickford and Schiel (1999) attributed lower catches at the beach to lower water clarity caused by sediment resuspension by wave action. Therefore, high current speeds at platforms may have indirectly affected light trap catch efficiency by reducing water clarity.

Results from this study have clear implications for future studies with light traps. At platforms, light trap CPUEs began to decline noticeably at current speeds of 30 cm/sec, and by 40 cm/sec catches of active swimming larval stages (i.e., all but preflexion stages) were rare. This finding suggests that, for comparison studies, estimates of relative abundance from light traps may be biased where there is considerable variation in current flow (Doherty, 1987; Anderson et al., 2002). Drifting traps may be used to avoid the confounding effect of differential water flow (Thorrold, 1992); however such a deployment method may not be applicable when habitats of interest are fixed (e.g., platforms, coral reefs). In such cases, the best course may be to not consider light trap samples at high current speeds (≥40 cm/sec). For turbidity, study results were not as clear; however, temporal or spatial variation in turbidity also would undoubtedly bias light trap results. Short of using light traps at times or locations of similar water clarity, an adjustable light source may be incorporated into light trap design so that equivalent light intensities, and therefore sampling fields, can be maintained across a variety of water conditions. The alternative would be to standardize the volumes of water sampled by light traps; however, considering the suite of external factors that affect light trap efficiency, such attempts may be fruitless (Meekan et al., 2000).

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